PB90-257791

Radon Mitigation Studies: Nashville Demonstration

Southern Research Inst., Birmingham, AL

Prepared for:

Environmental Protection Agency, Research Triangle Park, NC

Jul 90

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completi

1. REPORT NO. EPA-600/8-90-061	2.	3. PB90-257791

4. TITLE AND SUBTITLE Radon Mitigation Studies: Nashville Demonstration	5. REPORT DATE July 1990 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Bobby E. Pyle and Ashley D. Williamson	8. PERFORMING ORGANIZATION REPORT NC SRI-ENV-90-275-6411-10
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southern Research Institute P.O. Box 55305 Birmingham, Alabama 35255-5305	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. CR814621-01-0
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, North Carolina 27711	13. TYPE OF REPORT AND PERIOD COVEREI Final; 9/87-3/90 14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Michael C. Osborne, Mail Drop 54, 919/541-4113.

16. ABSTRACT

The report gives results of an EPA radon mitigation demonstration project involving 14 houses in the Nashville, TN, area with indoor radon levels of 5.6-47.6 pCi/L, using a variety of techniques, designed to be the most cost effective methods possible to implement, and yet adequately reduce radon levels to <4 pCi/L. For crawl space houses, the techniques included sealing openings between living areas and crawl spaces and then passively venting the crawl spaces, depressurizing the crawl spaces, depressurizing under polyethylene sheeting in the crawl spaces, and depressurizing the crawl space soil itself. For basement and basement/crawl space combination houses, the techniques included sub-slab pressurization and depressurization, block wall depressurization, and combinations of these techniques with some of those listed above for exposed soil areas. Post-mitigation worst-case radon levels in these houses were generally from <1 to about 5 pCi/L, with one house near 15 pCi/L. These houses are currently being followed with alpha-track detectors to assess the long term exposure levels.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Radon	Stationary Sources	07B
Residential Buildings	Indoor Air	13M

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 286
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB90-257791

EPA-600/8-90-061
July 1990

RADON MITIGATION STUDIES:
NASHVILLE DEMONSTRATION

Bobby E. Pyle
Ashley D. Williamson

Southern Research Institute
2000 Ninth Avenue South
P.O. Box 55305
Birmingham, AL 35255-5305

Cooperative Agreement No. CR-814621-01-0

EPA Project Officer: Michael C. Osborne
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

Prepared for:
U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

Disclaimer

The U.S. Environmental Protection Agency (EPA) strives to provide accurate, complete, and useful information. However, neither EPA nor any person contributing to the preparation of this document makes any warranty, expressed or implied, with respect to the usefulness or effectiveness of any information, method, or process disclosed in this material. Nor does EPA assume any liability for the use of, or for damages arising from the use of, any information, methods, or process disclosed in this document.

Mention of firms, trade names, or commercial products in this document does not constitute endorsement or recommendation for use.

ABSTRACT

In this EPA radon mitigation demonstration project, 14 houses in the Nashville, TN, area having indoor radon levels ranging from 5.6 to 47.6 pCi/L were mitigated using a variety of techniques. These techniques were designed to be the most cost-effective methods possible to implement and yet adequately reduce the radon levels to less than 4 pCi/L. For the crawl space houses, these techniques included sealing the openings between the living areas and the crawl space and then passively venting the crawl space, depressurizing the crawl space, depressurizing under polyethylene sheeting in the crawl space, and depressurizing the crawl space soil itself. In the basement and basement crawl space combination houses the techniques used included sub-slab pressurization and depressurization, block wall depressurization, and combinations of these techniques with some of those above for the exposed soil areas. Post-mitigation worst case radon levels in these houses generally ranged from less than 1 pCi/L to about 5 pCi/L with one house near 15 pCi/L. These houses are currently being followed with alpha-track detectors to assess the current long term exposure levels.

TABLE OF CONTENTS

Page

Abstract........ ii
Figures........ iv
Tables........ vi
Acknowledgements........ vii
Metric Conversion Factors........ viii

1. Introduction........ 1
   - Purpose........ 1
   - History........ 1
   - Problem........ 2
2. Conclusions and Recommendations........ 5
   - Methods Applied to Crawl Space Houses........ 5
   - Methods Applied to Basement or Combination Houses........ 6
   - Mitigation Costs........ 6
   - Recommendations for Additional Research........ 7
3. House Screening and Selection........ 9
4. Intensive Diagnostic Evaluation of Selected Houses........ 11
   - Soil Depressurization Test Results........ 15
   - Sub-Poly Depressurization Test Results........ 15
   - Leakage Area of Crawl Spaces, Houses and Floor Between........ 18
5. Development of Mitigation Plans........ 21
   - Crawl Space Houses........ 23
   - Basement Houses Converted from Crawl Spaces........ 47
   - Combination Basement/Crawl Space Houses........ 59
   - Slab-Below-Grade House........ 65
6. Mitigation of the Nashville Houses........ 69
   - Crawl Space Houses........ 74
   - Basement Houses Converted from Crawl Spaces........ 95
   - Combination Basement/Crawl Space Houses........ 101
   - Slab-Below-Grade Houses........ 106
7. Discussion of Results........ 111
   - Crawl Space Houses........ 111
   - Basement, Slab-On-Grade, and Combination Houses........ 121
8. Quality Assurance........ 133
   - Alpha Track Detectors........ 133
   - Charcoal Canisters........ 136
   - Continuous Radon Monitors........ 137

References........ 139

Appendix A. Homeowner Agreement Forms........ A-1
Appendix B. Continuous Radon Monitor Data........ B-1
Appendix C. Mitigation Costs........ C-1
Appendix D. Quality Assurance Correspondence........ D-1

FIGURES

Number | Page

1. Diagnostic test of sub-poly depressurization at DW90, Oct'87 17
2. House DW 03 crawl space layout 24
3. Sub-poly depressurization system for crawl space houses 26
4. House DW 27 crawl space layout 27
5. Crawl space depressurization detail 29
6. House DW 29 crawl space layout 31
7. House DW 31 crawl space layout 33
8. Sub-soil depressurization system detail 34
9. House DW 60 crawl space layout 36
10. House DW 66 crawl space layout 38
11. House DW 82 crawl space layout 40
12. Crawl space pressurization system 42
13. House DW 84 crawl space layout 44
14. House DW 90 crawl space layout 46
15. House DW 43 basement plan 48
16. Sub-slab plus block wall depressurization with varying suction pit shapes 50
17. House DW 58 basement/crawl space layout 52
18. Sub-slab plus sub-poly depressurization system 53
19. Sub-poly depressurization system detail for house DW 58 54
20. Basement pressurization system 56
21. House DW 78 basement/crawl space layout 57
22. House DW 12 basement floor plan 60
23. Sub-slab depressurization with varying pit size 61
24. House DW 14 basement layout 63
25. House DW 41 basement plan 66
26. Drain tile depressurization system 68
27. House DW 03 continuous radon levels measured in living room 75
28. House DW 27 continuous radon levels in living room 78
29. House DW 29 continuous rdon levels in den 80
30. House DW 31 continuous radon levels in den 83
31. House DW 60 continuous radon levels in living room 85
32. House DW 66 continuous radon levels in back bedroom 87
33. House DW 82 continuous radon levels in den 90
34. House DW 84 continuous radon levels in living room 92
35. House DW 90 continuous radon levels in living room 94
36. House DW 43 continuous radon levels in basement 96
37. House DW 78 continuous radon levels in basement 99
38. House DW 12 continuous radon levels in basement 102
39. House DW 14 continuous radon levels in basement 105
40. House DW 41 continuous radon levels in basement den 107

FIGURES (Continued)

41. Depressurization in soil of SSoD system at House DW 31............ 117
42. Depressurization in soil of SSoD system at House DW 84............ 118
43. Depressurization under poly of SPD systems....................... 120
44. Sub-slab pressure vs distance from suction hole at House DW 43.. 125
45. Relative sub-slab pressures vs suction pit shape measured at House DW 78.................................. 127
46. Relative sub-slab pressure vs suction hole B surface area at House DW 12...................................... 130
47. Relative sub-slab pressure vs suction hole surface area at House DW 14...................................... 132

TABLES

Number Page

1. Housing Types of the U.S. (1979-1981) 2
2. Results of the Nashville House Screening Evaluations 10
3. Houses Selected for Radon Mitigation by Category 10
4. Core Diagnostic Measurements 12
5. Nashville Pre-Mitigation Charcoal Results (Oct'87) 13
6. Pre-Mitigation Radon Grab Samples (Oct'87) 14
7. Soil Depressurization Test Results - Nashville, TN Oct'87 15
8. Sub-Poly Depressurization Test Results - Nashville, TN Oct'87 16
9. Leakage Areas of House and Crawl Space Diagnostic Tests for October, 1987 18
10. Matrix of Mitigation Techniques 22
11. Mitigation Schedule 70
12. Nashville Pre-Mitigation Charcoal Results (Nov'87 to April'88) 71
13. Pre-Mitigation Alpha Track Detector Results for Nashville Houses 72
14. Percent Radon Reduction for Each Crawl Space Mitigation Scheme (Based on Continuous Monitor Data in Living Area) 111
15. Nashville Radon Reduction Summary (Based on Charcoal Canister Measurements in pCi/L) 112
16. Soil ΔP Measurements at House DW31 115
17. Soil ΔP Measurements at House DW84 116
18. Pressure Measurements Under the Sheeting of Sub-Poly Depressurization Systems 119
19. Percent Radon Reduction for Each Basement Type Mitigation Scheme (Based on Continuous Monitor Data in Basement) 122
20. Effects of Suction Pit Shape on Sub-Slab Pressure Field Extension at House DW43 124
21. Effects of Suction Pit Shape on Sub-Slab Pressure Field Extension at House DW78 126
22. Sub-Slab Pressure Field Extension for Various Pit Sizes (Data taken at House DW12) 129
23. Sub-Slab Pressure Field Extension vs Pit Size (Data taken at House DW14) 129
24. Alpha Track Detector Blinds 135
25. Charcoal Canister Blinds 137
26. Continuous Passive Radon Detector Calibrations and Precision Measurements 138

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to several individuals and organizations for their efforts on behalf of this project. We would like to thank Terry Brennan, Wade Evans, and Drew Guillett of Camroden Associates for their assistance during the diagnostic evaluations and also for their cooperation in developing and implementing the mitigation plans for these houses. We want to especially thank Jackie Waynick and Susie Shimek of the Tennessee Department of Health and Environment, Air Pollution Control Division, and Patsy Brooks of EPA, Region 4, for their able and willing cooperation throughout this project. We also want to thank the EPA Project Officer for his capable and constructive assistance and support and, last but not least, the homeowners of the houses included in this study, whose patience and hospitality were invaluable.

METRIC CONVERSION FACTORS

Readers more familiar with the metric system may use the following factors to convert to that system.

Nonmetric	Multiplied by	Yields Metric
°F	5/9 (°F-32)	°C
ft	0.305	m
ft^2	0.093	m^2
ft^3	0.028	m^3
ft^3/min	0.00047	m^3/sec
gal.	3.785	L
in.	2.54	cm
in. wc	0.249	kPa
$in.^2$	6.452	cm^2
mil	25.4	μm
pCi/L	37.0	Bq/m^3

SECTION 1

INTRODUCTION

PURPOSE

The primary purpose of the work described in this report was to develop cost-effective techniques for radon mitigation in crawl space houses in the Nashville Metropolitan Area. These techniques should also be applicable to crawl space designs in other parts of the country. Other types of houses mitigated during this study were basement houses in which the basement was excavated from an existing crawl space. Unlike many houses with basements and adjoining crawl spaces, in many of these houses there remain areas of exposed soil in open communication with the basement. This type of construction is also typical of the mid-south areas and hence offers yet another opportunity to expand the existing data base of radon reduction techniques.

Another purpose for this mitigation demonstration was to train local contractors in the proper techniques of radon mitigation and thereby encourage radon mitigation efforts by the private sector. This will hopefully result in providing sources of cost-effective and successful mitigation installations to homeowners in this region. The results described in this report are the initial results of an ongoing, EPA funded, radon mitigation demonstration in existing houses in the Nashville area.

HISTORY

The State of Tennessee, operating through the Tennessee Department of Health and Environment - Division of Air Pollution Control (TDHE), and in cooperation with the U.S. Environmental Protection Agency (EPA) State Radon Survey Program, conducted a survey to identify areas within the state having the potential for elevated radon levels in privately owned houses[1]. During the months of January through April 1987, approximately 1,787 measurements were carried out in single-family owner-occupied houses. Based on the results of that survey, the Division of Air Pollution Control estimated that 84.2% of the houses in the state have radon levels below 4 picocuries per liter (pCi/L)*, 14.5% have levels between 4 and 20 pCi/L, and 1.3% have levels equal to or greater than 20 pCi/L. The highest level detected in this survey was 99.9 pCi/L. From the geological character of the soils and rocks in the various parts of the state, four levels of risk for indoor radon were developed (High, Intermediate, Moderate, and Low). The High Risk areas form a two-pronged band through the central part of the state. This High Risk band includes the greater part of Davidson County, which also happens to be one of the most populated counties in the state.

(*)Readers more familiar with metric units may use the factors listed at the end of the front matter of this report to convert to that system.

PROBLEM

The state of Tennessee, along with several other states, contain a substantial number of crawl space houses for which there is very little data regarding the appropriate technique to use for radon mitigation. This construction type represented from 16 to 28% of the housing starts nationwide over the period 1963 to 1983[2]. States having a significant fraction of crawl space houses include Oregon, South Carolina, North Carolina, Nevada, Tennessee, Delaware, Arkansas, New Jersey, Idaho, Washington, West Virginia, Alabama, Virginia, and others with less than 25% each. The distribution of house type by state[3] is shown in TABLE 1. Thus the crawl space house represents a significant fraction of the existing housing stock in diverse regions of the U.S.

In general, crawl space houses can be defined as those in which a part or all of the living areas of the house are built over an enclosed area containing exposed earth. Clearance in this enclosed area can vary with the house type and site geometry from a few inches below the floor joists to several feet. In most cases the clearance is sufficient so that access can be gained through the outside wall of the house foundation. However, in some houses access can only be gained through the floor of the house itself. Prior to the collection of recent radon data[4], crawl spaces were even considered to be a viable alternative for radon control in new construction[5].

TABLE 1. HOUSING TYPES OF THE U.S. (1979-1981)[3]

State Code	State Name	Percent Basement	Percent Crawl Space	Percent Slab-on-Grade	Percent Total
OR	Oregon	23.0	72.5	4.5	100.0
SC	S.Carolina	8.5	62.5	30.0	101.0
NC	N.Carolina	16.5	56.0	27.5	100.0
NV	Nevada	0.5	46.0	53.5	100.0
TN	Tennessee	28.5	44.0	27.5	100.0
DE	Delaware	30.5	41.0	28.5	100.0
AR	Arkansas	9.5	41.0	49.5	100.0
NJ	New Jersey	32.0	41.0	7.0	80.0
ID	Idaho	58.0	40.0	1.5	99.5
WA	Washington	62.5	35.0	2.5	100.0
WV	West Virginia	53.5	32.5	14.0	100.0
AL	Alabama	10.5	30.5	59.0	100.0
VA	Virginia	47.0	25.0	28.0	100.0
IN	Indiana	42.5	23.0	34.5	100.0
GA	Georgia	40.0	22.5	37.5	100.0

(continued)

TABLE 1. (continued)

State Code	State Name	Percent Base-ment	Percent Crawl Space	Percent Slab-on-Grade	Percent Total
CA	California	11.5	19.5	69.0	100.0
CO	Colorado	80.1	19.1	1.0	100.2
KY	Kentucky	72.0	18.5	9.5	100.0
NH	N.Hampshire	79.0	16.0	3.0	98.0
OH	Ohio	75.5	10.5	14.0	100.0
WY	Wyoming	90.5	9.0	0.5	100.0
IL	Illinois	80.0	7.5	12.5	100.0
VT	Vermont	86.5	6.0	7.5	100.0
FL	Florida	0.0	5.0	95.0	100.0
MS	Mississippi	2.0	5.0	95.0	102.0
IA	Iowa	94.0	4.5	1.5	100.0
NY	New York	81.5	4.0	14.5	100.0
PA	Pennsylvania	92.0	4.0	4.0	100.0
SD	S.Dakota	89.5	3.5	7.0	100.0
NM	New Mexico	1.5	3.0	95.5	100.0
KS	Kansas	96.0	3.0	1.0	100.0
UT	Utah	95.0	3.0	2.0	100.0
AZ	Arizona	1.5	3.0	97.5	102.0
MI	Michigan	96.5	3.0	0.5	100.0
NE	Nebraska	93.5	3.0	1.5	98.0
ND	N.Dakota	95.0	2.5	2.5	100.0
MD	Maryland	92.0	2.5	5.5	100.0
MO	Missouri	93.5	2.0	4.5	100.0
ME	Maine	93.0	2.0	5.0	100.0
CT	Connecticut	96.0	2.0	2.0	100.0
MA	Maine	94.0	2.0	4.0	100.0
MT	Montana	98.5	1.5	0.0	100.0
OK	Oklahoma	3.0	1.0	96.0	100.0
WI	Wisconsin	90.5	1.0	8.5	100.0
MN	Minnesota	98.5	1.0	0.5	100.0
LA	Louisiana	3.5	0.5	96.0	100.0
RI	Rhode Island	97.5	0.5	2.0	100.0
TX	Texas	1.5	0.0	98.5	100.0

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Several different techniques have been tested in crawl space and combination houses typical of the southeast. Based upon the results described in the remainder of this report the following conclusions can be drawn.

METHODS APPLIED TO CRAWL SPACE HOUSES

- Isolation of the crawl space from the living areas of the house was found to be difficult if not impossible to achieve and its use as the only mitigation technique is risky, questionable, and not recommended.
- Isolation and passive ventilation of the crawl space using only the existing foundation vents was found to be ineffective due to the limited area of the vents installed in most houses. This technique is not recommended as the sole mitigation method even if it is combined with covering the soil in the crawl space with some type of plastic film. Without active ventilation under the film, the radon levels in the living areas will, in all likelihood, not be reduced to acceptable limits.
- Isolation and depressurization of the crawl space was found to be an effective method of reducing the radon levels in the living areas of one house. However, this technique can substantially increase the levels in the crawl space. This technique may be difficult to apply when there are cold air return ducts in the crawl and could also incur an energy loss from the conditioned air space above.
- Sub-soil depressurization was found to be an effective technique for two houses in this study. Its effectiveness is greatly influenced by the soil conditions in the crawl and should be used with caution until additional results from other geographic locations and soil conditions become available.
- Sub-membrane depressurization in the crawl space was the most widely applicable technique in this study and proved a reliable method of removing the radon before it enters the crawl. The number of suction points needed under the membrane will depend upon both the crawl space area and the condition of the soil. For areas over 1,200 ft^2 or crawls with execssively damp soil conditions, at least two suction points should be installed at opposite ends of the crawl. The membrane used in these houses was standard 6 mil clear builders polyethylene. However, due to its limited puncture and tear resistance and its instability to ultraviolet (uv) light degradation, it is not recommended for more general use. Instead, a cross-laminated, high density polyethylene material with uv stabilizers is recommended. Sealing of the membrane lap joints and

to the surrounding foundation walls and support piers is recommended at locations within 12 feet of the suction point(s) and at all locations if the crawl space is exceptionally large. In this case it may even be necessary to install some type of drainage system under the membrane to improve the air flow.

METHODS APPLIED TO BASEMENT OR COMBINATION HOUSES

- Sub-slab pressurization was found to be somewhat effective for radon reduction in one house but not as effective as depressurization of the sub-slab region. It also can produce other problems such as increased moisture or even increased levels of termaticide in the basement. It may be difficult to apply when sub-slab communication is poor.

- Sub-slab depressurization (or sub-slab ventilation) was found to be an effective technique in the five houses studied even when the sub-slab communication was not very good. In these cases, more than one suction hole will likely be required. The soil under the slab, at the suction point should be excavated to at least a diameter of about 36 inches and to a depth of about 12 to 18 inches. The amount of soil surface area exposed in the pit is more important than the depth or shape of the pit. Filling the pit with crushed stone was not found to be necessary.

- Block wall depressurization was found to improve the effectiveness of sub-slab systems in the three houses in which it was applied in this study. In these houses large areas of the block wall were either below grade or served to separate the crawl space from the basement. Sealing of the wall was found to be necessary in one case in which the porous blocks short-circuited the negative pressures generated under the slab.

- Consideration of the exposed soil in direct communication with the basement was found to be essential to lowering the radon levels to acceptable limits. The methods used for these areas are similar to those for crawl spaces above.

MITIGATION COSTS

The actual contractor costs for installing the systems in the crawl space houses of this study ranged from a low of $850 to a high of $1,859 with an average cost of $1,282. For the basement and basement-combination houses, the costs ranged from a low of $785 to a high of $1,995 with an average cost of $1,496. A more complete table of costs is shown in Appendix C. However, these costs do not include any time spent in diagnostics or in design of the mitigation systems. The expenses incurred by private mitigators for these latter items could increase the costs by as much as 25 to 50 percent.

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

There are questions that need to be addressed in future studies of mitigation using the techniques described above. In the sub-poly depressurization technique, the material used for these houses was standard builder grade 6 mil polyethylene sheeting. The properties of this material (thickness, puncture resistance, permeability) vary from location to location in a single sheet. Also, the tear and puncture resistance is not believed to be sufficiently high to withstand normal traffic (such as by service personnel from the utility companies, the termite control organizations, or by the homeowner) that might be expected in a crawl space. Other materials such as cross-laminated high-density polyethylene films or lagoon liners need to be examined for use in these applications.

In those houses for which sub-slab depressurization cannot be made to function in a cost-effective manner, other techniques such as basement pressurization need to be developed and demonstrated.

SECTION 3

HOUSE SCREENING AND SELECTION

The houses for this demonstration were selected from respondents to a media announcement for homeowners whose houses had previously been tested and found to contain elevated levels of radon (greater than 4 pCi/L). From approximately 100 respondents, 30 houses were selected for screening as possible candidate for participation in the radon mitigation demonstration. These 30 houses in Davidson and Williamson Counties (in and near Nashville, TN) were screened between September 8 and 11, 1987, by a team of scientists from EPA, Tennessee Department of Health and Environment, Southern Research Institute, and Camroden Associates. The purpose of the screening effort was to evaluate the houses for possible inclusion in the first phase of the Middle Tennessee radon mitigation demonstration. The following criteria were used to facilitate rank-ordering the houses following each day's screening efforts:

1. Potential for providing radon reduction information that had not been previously collected. This could be based on features of the house or mitigation measures that could be attempted.

2. Applicability of radon reduction results for this house to other installations. A one-of-a-kind house would score very low in this category. Also, individual unique features could lower the score.

3. Difficulty factor - considerable work required with limited value obtained for the effort. For example, a crawl space too cluttered to enter would receive a low score.

4. Accessibility and homeowner cooperation. For example, a homeowner who refused to allow the team to drill holes in the slab would get a low score.

5. Relationship to other houses that might be included in this study. Two adjacent houses with similar construction style and radon levels would each score high in this category.

Screening of the 30 houses was carried out by two teams with at least five members in each. The 30 houses were divided into two groups of 15 houses according to house sub-structure type. The two types were generally crawl space houses and houses with basements or slabs. Some of the basement houses were actually converted crawl spaces.

In each team the house assessment tasks were divided into five categories as follows:

A. Team Diagnostician
B. Grab Sampler/Assistant
C. Homeowner Interaction Coordinator
D. Draftsman
E. Blower Door and/or Halogen Detector Operator.

The results of this screening evaluation are summarized in TABLE 2 where the ranking scores received by each of the 30 houses are tabulated by team and in descending order of ranking. Also shown in this TABLE are those houses that were rejected outright and the criterion used for their rejection.

TABLE 2. RESULTS OF THE NASHVILLE HOUSE SCREENING EVALUATIONS

Team A (Crawl spaces)		Team B (Basements)	
House ID	Score	House ID	Score
DW 90	95	DW 43	95
DW 29	94	DW 14	85
DW 84	90	DW 78	80
DW 31	89	DW 12	80
DW 82	89	DW 41	75
DW 60	88	DW 63	75
DW 27	85	DW 58	70
DW 66	83	DW 75	65
DW 03	74	DW 81	Rejected (Criteria #1)
DW 92	63	DW 10	Rejected (Criteria #1)
DW 28	62	DW 79	Rejected (Criteria #2)
DW 67	Rejected (Criteria #1)	DW 20	Rejected (Criteria #3)
DW 93	Rejected (Criteria #1)	DW 26	Rejected (Criteria #3)
DW 23	Rejected (Criteria #3)	DW 57	Rejected (Criteria #3)
DW 68	Rejected (Criteria #3)	DW 64	Rejected (Criteria #3)

As a result of these screening visits, 15 houses were selected to be included in the mitigation demonstration program. The houses selected are shown in TABLE 3. and include nine crawl space houses, three houses with basements converted from crawl spaces, two combination basement/crawl space houses, and one slab-below-grade house. This cross section is representative of the existing houses in the Nashville area and in portions of other states in the mid-south.

TABLE 3. HOUSES SELECTED FOR RADON MITIGATION BY CATEGORY

Crawl space	Basement Converted Crawl	Slab-below-grade	Combination Basement/crawl
DW 90	DW 43	DW 41	DW 12
DW 29	DW 58		DW 14
DW 84	DW 78		
DW 31			
DW 82			
DW 60			
DW 27			
DW 66			
DW 03			

SECTION 4

INTENSIVE DIAGNOSTIC EVALUATION OF SELECTED HOUSES

An additional extensive diagnostic visit to each house was conducted between October 21 and 27, 1987. During this visit, measurements and investigations were carried out in order to develop radon reduction plans that would fit into the overall research objectives of the project. Since each house had already been visited during the selection process, the buildings had been inspected and site forms filled out at that time. Thus, to make the best use of field time, a checklist of core measurements common to all houses was developed in advance. Several mitigation strategies had been identified along with additional tests and observations to be carried out specific to each house. Two mitigation strategies had been planned for temporary implementation during the diagnostic test week in October.

The core measurements checklist is shown in TABLE 4. These extensive diagnostic measurements are seldom carried out by the private mitigator, primarily because of costs and the lack of necessary instrumentation. Their purpose in this study was to gain fundamental information about the various parameters of the house and soil and their interactions. The results of specific tests carried out at each house and the trial mitigation strategies tested at some of the houses are discussed in the following paragraphs.

Charcoal canisters (CCs) and alpha track detectors (ATDs) were placed in either the crawl space or the basement and on the first habitable level of each of the houses to obtain a pre-mitigation radon background. In each location, duplicate detectors were collocated in an effort to determine the variation that could be expected in these houses. The CCs were recovered by the homeowner after 48 hours and mailed to the analysis laboratory (Scientific Analysis, Inc., Montgomery, AL). The ATDs were left in the houses until just prior to installation of the mitigation equipment. At that time they were returned to the supplier for analysis (Terradex Corp., Glenwood, IL).

The results from the collocated CC measurements in October 1987 are shown in TABLE 5. Also, during the intensive diagnostic visit at each of the houses, radon grab samples of the air were taken in two locations in each of the houses (with the exception of DW 41). The results of these grab samples are shown in TABLE 6.

TABLE 4. CORE DIAGNOSTIC MEASUREMENTS

A. Grab or sniffer measurements
   1. Grab in open basement or crawl space
   2. Sniffer measurement of sub-slab or soil air from crawl space
   3. Sniffer measurements in center of each wall of basement or foundation
   4. Sniffer measurements in obvious penetrations (sumps, drains, cracks, and around pipes)
   5. Grab samples in accumulator cans in crawl spaces
   6. EPA protocol grab measurements of upstairs air

B. Communication Measurements
   1. Crawl to house leakage areas
   2. Smoke or freon tests of air flow

C. Infiltration / Tightness
   1. Fan door tests of:
      a. Whole house to outside air (ASTM protocol)
      b. Basement air to upstairs air (Camroden protocol)
      c. Upstairs door by opening all windows and doors upstairs

D. ΔP Measurements
   1. Crawl or basement to outside air with furnace on then off
   2. Crawl or basement to upstairs air

E. Gamma Measurements
   1. Survey for elevated levels in building materials
   2. Survey for radon in water (gamma buildup in water conditioner)
   3. Survey of concentrations around house and lot

TABLE 5. NASHVILLE PRE-MITIGATION TWO-DAY CHARCOAL RESULTS FOR OCTOBER, 1987 (Results in pCi/L)

House ID #	Crawl Space		Basement		1st Habitable Level	
DW 03	22.0	21.9	NA	NA	9.6	9.5
DW 12	NA	NA	26.4	25.7	20.2	19.1
DW 14	NA	NA	33.2	31.0	16.0	16.0
DW 27	64.1	65.2	NA	NA	39.9	40.3
DW 29	13.2	*	NA	NA	5.8	5.7
DW 31	29.0	16.5**	NA	NA	22.7	23.2
DW 41	NA	NA	30.1	28.6	18.7	19.2
DW 43	NA	NA	48.3	48.4	16.5	17.0
DW 58	NA	NA	43.0	43.5	36.1	36.0
DW 60	34.8	32.2	NA	NA	20.5	20.5
DW 66	20.0	19.2	NA	NA	12.1	9.9
DW 78	NA	NA	41.2	42.3	21.8	21.4
DW 82	27.3	27.2	NA	NA	15.4	14.2
DW 84	8.9	9.1	NA	NA	5.7	5.5
DW 90	18.0	16.9	NA	NA	8.4	7.7

NA - Not Applicable
* This detector lost
** Top left off can in shipment

TABLE 6. PRE-MITIGATION RADON GRAB SAMPLES FOR OCTOBER, 1987

House ID	Location	Date Sampled	pCi/L
DW - 03	Crawl Spc	10/26/87	13.5
DW - 03	Bdrm Hall	10/26/87	5.3
DW - 12	Basement	10/22/87	13.4
DW - 12	Living Rm	10/22/87	11.2
DW - 14	Basement	10/22/87	38.2
DW - 14	Living Rm	10/22/87	31.9
DW - 27	Crawl Spc	10/24/87	1.8
DW - 27	Living Rm	10/24/87	8.0
DW - 29	Crawl Spc	10/23/87	5.6
DW - 29	Living Rm	10/23/87	4.7
DW - 31	Crawl Spc	10/23/87	15.3
DW - 31	Living Rm	10/23/87	19.3
DW - 41	Bsmt Den	10/22/87	14.8
DW - 43	Basement	10/21/87	30.0
DW - 43	Living Rm	10/21/87	15.2
DW - 58	Basement	10/21/87	45.9
DW - 58	Living Rm	10/21/87	29.1
DW - 60	Crawl Spc	10/26/87	16.3
DW - 60	Bedroom	10/26/87	14.4
DW - 66	Crawl Spc	10/27/87	1.5
DW - 66	Back Bdrm	10/27/87	2.5
DW - 78	Basement	10/21/87	18.1
DW - 78	Dining Rm	10/21/87	15.8
DW - 82	Crawl Spc	10/26/87	2.3
DW - 82	Living Rm	10/26/87	0.97
DW - 84	Crawl Spc	10/23/87	7.1
DW - 84	Living Rm	10/23/87	0.35
DW - 90	Crawl Spc	10/24/87	0.53
DW - 90	Living Rm	10/24/87	9.2

SOIL DEPRESSURIZATION TEST RESULTS

At five houses a pit about 20 in. wide and 12 in. deep was excavated and an RDS blower was used to apply suction through a 4 in. flexible duct. The hole was covered with a 30 in. square piece of Bainbridge board and sealed at the edges by piling earth excavated from the hole on top of the board. Holes 3/8 in. in diameter were drilled in the soil at distances of 2 ft, 6 ft, and 12 ft from the suction pit. Fan flow and pressure differential was measured between the crawl space air and the suction pit and the 3/8 in. holes. This provided an estimate of the extent of the pressure field induced in the soil by the fan.

The results of the tests shown in TABLE 7 were encouraging enough to warrant trying this technique, especially at DW31. The pressure field extended through the soil reasonably well in house DW31, but not in the others. This is a function of soil character because DW31 had a dry, fine powdery soil and all the other houses had hard, sometimes fractured clay. Based on the fan flowrates in TABLE 7, it appears that all the other houses tested were getting as much or more air as DW31. This is consistent with the fact that in DW31 the air flow was probably through the porous soil rather than through large air spaces in the soil. On the assumption that in the remaining houses the air was being drawn in through fractures and not from edge leaks around the board, then it is possible this method would work in those houses by ventilating the fractures and fissures in the soil. None of the tests showed very high flowrates, and all showed results that would appear reasonable on the fan flow - ΔP curve for the blower used.

TABLE 7. SOIL DEPRESSURIZATION TEST RESULTS
FOR OCTOBER, 1987

House ID #	Fan Flow Rate (cfm)	ΔP Source (in.WC)	ΔP at 2 ft (in.WC)	Smoke Flow	ΔP at 6 ft (in.WC)	Smoke Flow	ΔP at 12 ft (in.WC)	Smoke Flow
DW 27	60	-1.039	0	down	0	NC	0	NC
DW 84	70	-1.11*	-0.001	down	-0.001	down	0	NC
DW 82	35	-1.55	-0.005	NC	0	NC	NC	NC
DW 90	36	-1.39	0	NC	0	NC	0	NC
DW 31	28	-1.56	-0.016	NC	-0.003	NC	NC	NC

NC - no noticeable change
* - this value recorded as -0.111 but -1.11 is more likely

SUB-POLY DEPRESSURIZATION TEST RESULTS

The RDS blower was used to apply suction under the existing poly at five of the houses. Flowrates and pressure checks were made similar to the ones done on the soil depressurization tests. The results are shown in TABLE 8. These results were very encouraging since in all cases, a pressure field was extended a great distance under the poly sheets.

TABLE 8. SUB-POLY DEPRESSURIZATION TEST RESULTS
FOR OCTOBER, 1987

House ID #	Fan Flow Rate (cfm)	ΔP (in.of water) Measured Relative To Crawl Space						
		At Source	At 2 ft	Smoke Flow*	At 6 ft	Smoke Flow*	At 12 ft	Smoke Flow*
DW 60	30	-0.26	-0.02	down	-0.003	down	-0.001	down
DW 29	69	NA	-0.368	down	-0.05	down	-0.003	down
DW 03	NA	NA	NA	down	NA	down	NA	down
DW 90	35	-0.025	-0.16	down	NA	down	-0.007	down
DW 66	33	-0.025	-0.019	down	-0.002	down	-0.001	down

* - Direction of airflow immediately above the poly
NA - Data not available or not observed

Two additional experiments were done along this line. In the first, the fan flow was observed to decrease with time. This was interpreted as the poly being pressed tighter and tighter to the ground by the air pressure differential. For example, in house DW90 the flow started out at 49 cfm and ended 20 minutes later at 26 cfm. In DW60 it started at 35 cfm and went quickly to 30 cfm where it remained stable for 10 minutes (the end of the test).

The second experiment was performed at house DW90 and was a most significant test. At this house the vents were sealed and a continuous passive radon monitor was installed in the crawl space for a day before the sub-poly suction was applied and then run over the weekend to see the effect of the suction. Even though the poly only covered about 50% of the crawl space floor, the impact on crawl space air concentrations was dramatic. The results of the monitoring are shown in Figure 1. The large radon reduction may be due to a combination of soil depresssurization, dilution (25-35 cfm), and depressurization of the crawl space (although it is doubtful that the removal of 30 cfm would depressurize the crawl space by any measurable amount because it took 1100 cfm to depressurize it to -10 Pascals with the fan door). The fan door measurement estimates that if the crawl space were simply a small building it would have an average infiltration rate of about 130 cfm, and adding 30 cfm more should reduce the radon levels by about 19% (bearing in mind that there is substantial uncertainty about the ventilation measure). It is thought that the major mechanism at work is soil depressurization.

This appears to be a good technique for further experiments, especially for low and moderate level houses, because it is very easy and inexpensive to install and is something that can be accomplished by many do-it-yourselfers. This technique is not an engineered-with-new-materials-controls-system but is a simple, functional system that takes advantage of conditions as they exist and is less amenable to specification and control by an engineer or designer.

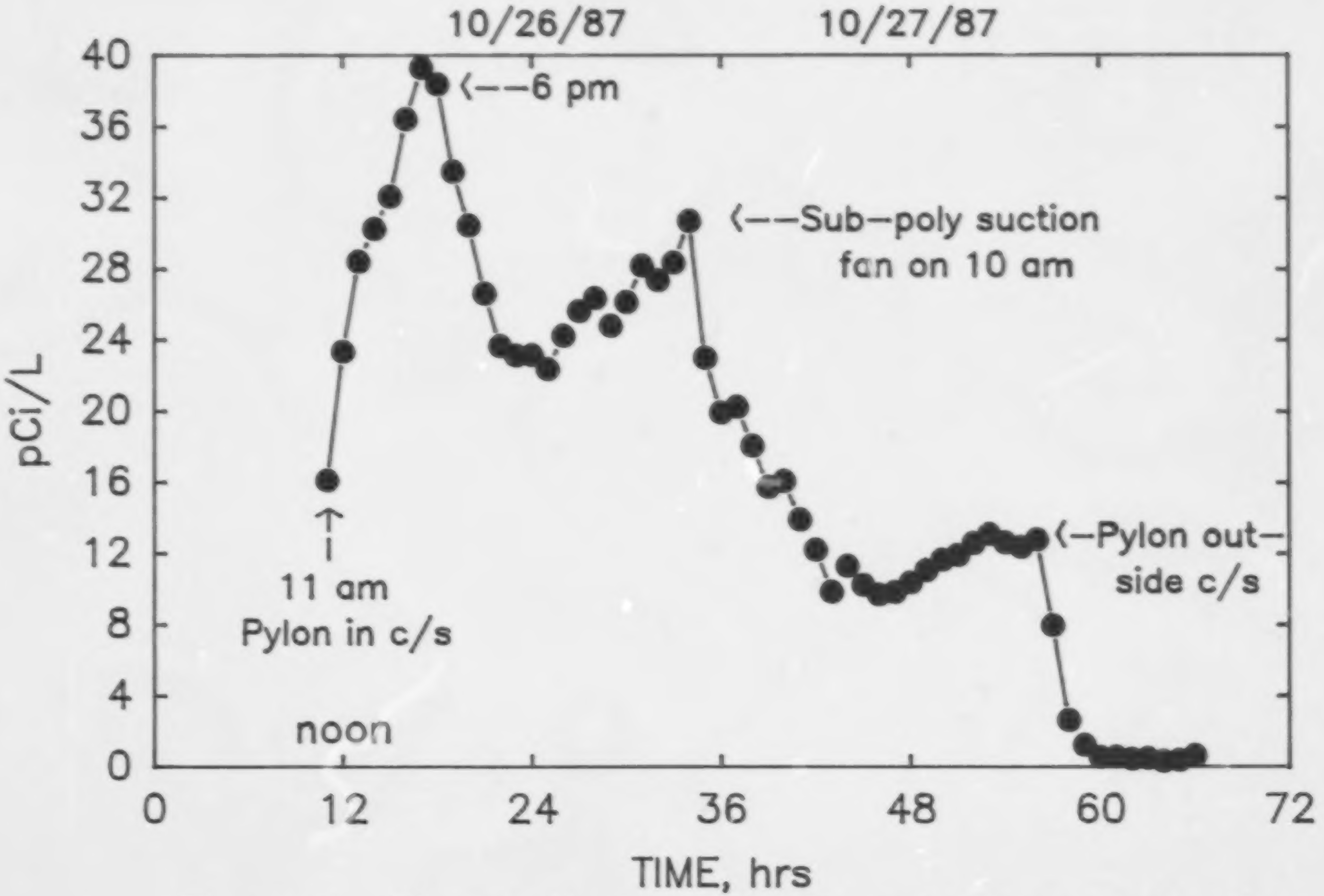


Figure 1. Diagnostic test of sub-poly depressurization in crawl space (c/s) of house DW90, Oct. 1987.

LEAKAGE AREA OF CRAWL SPACES, HOUSES, AND FLOOR BETWEEN

Fan depressurization tests were performed on:

- house only
- crawl space only
- crawl space and house simultaneously so that the pressure differential between the house air and the crawl space air was zero.

By doing this, the leakage area of the floor between the house and crawl space could be determined by subtracting the leakage area of house crawl space double fan test from the leakage area of the house only. This was done on the nine crawl space houses, and the results are presented in TABLE 9. The houses themselves are typical in leakage area, averaging 165 square inches and ranging from 54 to 295 square inches. The crawl space leakage areas are all very high (with vents closed), averaging 262 square inches and ranging from 198 to 425 square inches. At house DW27 the crawl space was tested with vents open and with vents closed. The vents open condition added about 200 square inches to the leakage area, almost doubling the leakage area with vents closed. Subtracting the house leakage area less floor from the house only leakage area gave an average connecting floor leakage area (column 8 of TABLE 9) of 55 square inches with a range from 10 to 128 square inches. The 55 square inch average represents a fairly large hole when compared to the average total leakage area for the houses of 165 square inches. It was clear from these measurements that there was a large enough leakage area in these floors for crawl space air to enter the living space.

TABLE 9. LEAKAGE AREAS OF HOUSE AND CRAWL SPACE
DIAGNOSTIC TESTS FOR OCTOBER, 1987

House ID#	House Volume (ft^3)	Crawl Volume (ft^3)	House ELA (in^2.)	House Less Floor ELA (in^2.)	Crawl ELA (in^2.)	Crawl Less Floor ELA (in^2.)	Floor ELA (in^2.)	Air Ducts in Crawl
DW84	16800	5200	155	120	239	237	35	Y
DW60	9600	3600	295	207	198	255	88	N
DW29	15576	4400	236	174	424	351	62	Y
DW90	10752	2700	96	70	203	193	26	N
DW31	9600	1875	54	23	213	220	31	N
DW66	14400	5000	179	54	272	239	125	Y
DW03	8800	3000	132	96	217	379	36	N
DW27	16000	8000	197	119	297	228	78	Y
DW82	12200	4550	144	134	298	273	10	N
Ave -	12636	4258.3	165.3	110.8	262.3	263.9	54.56	

An interesting note from these measurements is that the houses with air ducts in the crawl space (DW27, DW29, DW66, and DW84) have an average of 75 square inches leakage area through the floor (ranging from 35 to 125 square inches), and the houses with no ducts in the crawl space had a much lower average leakage area of 38 square inches (ranging from 10 to 88 square inches). These results suggest that the ductwork provides air routes from the crawl space to the house. Although this is not conclusive evidence, it is supported by observations using smoke sticks that showed air flow from the crawl space into the ductwork when the air circulation blower was on. This was later confirmed by physical observations in one house in particular (DW29) where the house floor joists were used as two sides of the return air plenum. Cracks produced by board shrinkage and gaps left by the builders resulted in large openings for crawl space air entry into the ducts.

SECTION 5

DEVELOPMENT OF MITIGATION PLANS

The mitigation techniques for each of the 15 houses in Nashville, TN, were developed by Camroden Associates and SRI following the diagnostic visits to each of the houses in October 1987. For each of the houses a 2 or 3 phase mitigation strategy was developed following the guidelines established by the EPA Project Officer. These guidelines were as follows:

- Phase 1 should be a low-cost alternative (less than $500 if possible) that can be easily removed or turned off
- Phase 2 should be a technique with a high probability of lowering the house radon levels to 4 pCi/L or less and of moderate cost ($500 - $2,000)
- Phase 3 should be as close to a guaranteed reduction method as possible with correspondingly higher cost (up to $5,000).

During the planning stages it was anticipated that no more than 25% of the houses would require the implementation of a Phase 3 system. In an effort to obtain the maximum scientific benefit, it was also assumed that the Phase 2 systems would be installed and tested even if the Phase 1 systems achieved levels less than 4 pCi/L.

The mitigation strategies for each house were developed using as a basis the information obtained during both the screening and diagnostic visits. This information included the type of house construction, condition of the house flooring, whether there was HAC ducting in the crawl space, the extent and condition of any existing polyethylene sheeting under the house, the existence of a basement and the condition of the slab, the existence of any exposed soil areas in the basement, and the condition of the soil in the crawl space. From these site conditions and a list of the possible mitigation systems that could be applied to the Nashville houses, a matrix of mitigation strategies was developed that would hopefully evaluate, demonstrate, and allow comparisons of each technique to arrive at those methods that would be both successful and cost-effective for houses similar to those in Nashville. The mitigation matrix is shown in TABLE 10.

In the following paragraphs, the mitigation strategies developed for each house, along with the evaluation schedules, are discussed. These are grouped by house type with the crawl space houses first, the basements converted from crawl spaces second, the combination basement crawl spaces third, and the slab-below-grade last. Some of these mitigation strategies were never implemented and are described for completeness only.

TABLE 10. MATRIX OF MITIGATION TECHNIQUES

Technique	Mitigation Phase by House ID (DW)																	
	03	27	29	31	60	66	82	84	90		43	58	78		12	14		41
ICS			*1			1												
IVCS	1	2			1				1									
IDCS		3		2			2											
IPCS							1											
SSoD				1				1										
SPD	2	1	2		2	2		2	2									
SSD-W											2	1	2					2
SSD-N											1		1					
SSD-P															1	1		
SSBWD											3		3			2		
SSSPD													+4		2	3		
PB												2	+5					
SSP															3			1
DTD																		3

Notes:
* - Numbers refer to phases of mitigation application
ICS - Isolation of Crawl Space
IVCS - Isolation and Ventilation of Crawl Space
IDCS - Isolation and Depressurization of Crawl Space
IPCS - Isolation and Pressurization of Crawl Space
SSoD - Sub-soil Depressurization
SPD - Sub-poly Depressurization
SSD-W - Sub-slab Depressurization Wide Pit
SSD-N - Sub-slab Depressurization Narrow Pit
SSD-P - Sub-slab Depressurization Progressive Pit
SSBWD - Sub-slab + Block Wall Depressurization
SSSPD - Sub-slab + Sub-poly Depressurization
PB - Pressurization of Basement
SSP - Sub-slab Pressurization
DTD - Drain Tile Depressurization
+ - In house DW78, two additional phases were scheduled.

CRAWL SPACE HOUSES

House DW03 Mitigation Strategies

This house has a crawl space of approximately 1100 ft^2 with a slab-on-grade garage with an area of 483 ft^2. There were no HAC ducts in the crawl space at the time of mitigation. The layout of the crawl space is shown in Figure 2.

Phase 1 - Isolation and Ventilation of Crawl Space (IVCS)--

The first technique, IVCS, was considered for this house because the floor between the living space and the crawl space was already insulated, there were no HAC ducts in the crawl space to be considered, and the crawl already had vents. All that was required was to seal the openings in the overhead floor using caulks and foams, to insulate the water pipes using closed-cell pipe insulation, to insulate the wasteline pipes with fiberglass insulation wrap, and to leave open a number of vents during the winter months.

The following locations in the floor or structure were to be sealed.

- Around termite shield and block cracks with polyurethane caulk
- Around pipe entries (toilet and tub) with caulk and foam
- Around access door to tub with caulk
- The vent into garage was to be sealed with foam board and caulk
- Any other large, easily accessible, openings between the crawl space air and the upstairs air also were to be sealed.

During testing, two vents on opposite walls of the crawl space were to be left open. These vents were to be selected to minimize the possibility of freeze damage to water pipes.

Phase 2 - Sub-Poly Depressurization Under New/Existing Polyethylene (SPD)--

The second technique was chosen because it was inexpensive and simple to implement in houses that have a vapor barrier already down on the earth. Part of the goal was to determine how much sealing must be done and how many suction points were needed in order to make it work.

The existing crawl floor of this house was about 70% covered with poly, but only about 50% was in good condition. Preliminary experiments showed good pressure field development 12 ft from the suction point. The remaining bare soil and the parts of the soil that had poly in poor condition were to be covered with new 6 mil poly film. This was to be installed to provide continuous coverage with no earth exposed but with no special attempts to seal the edges of the poly to walls, support posts or edges. However, the edges of the poly sheets were to be overlapped by a minimum of 12 in.

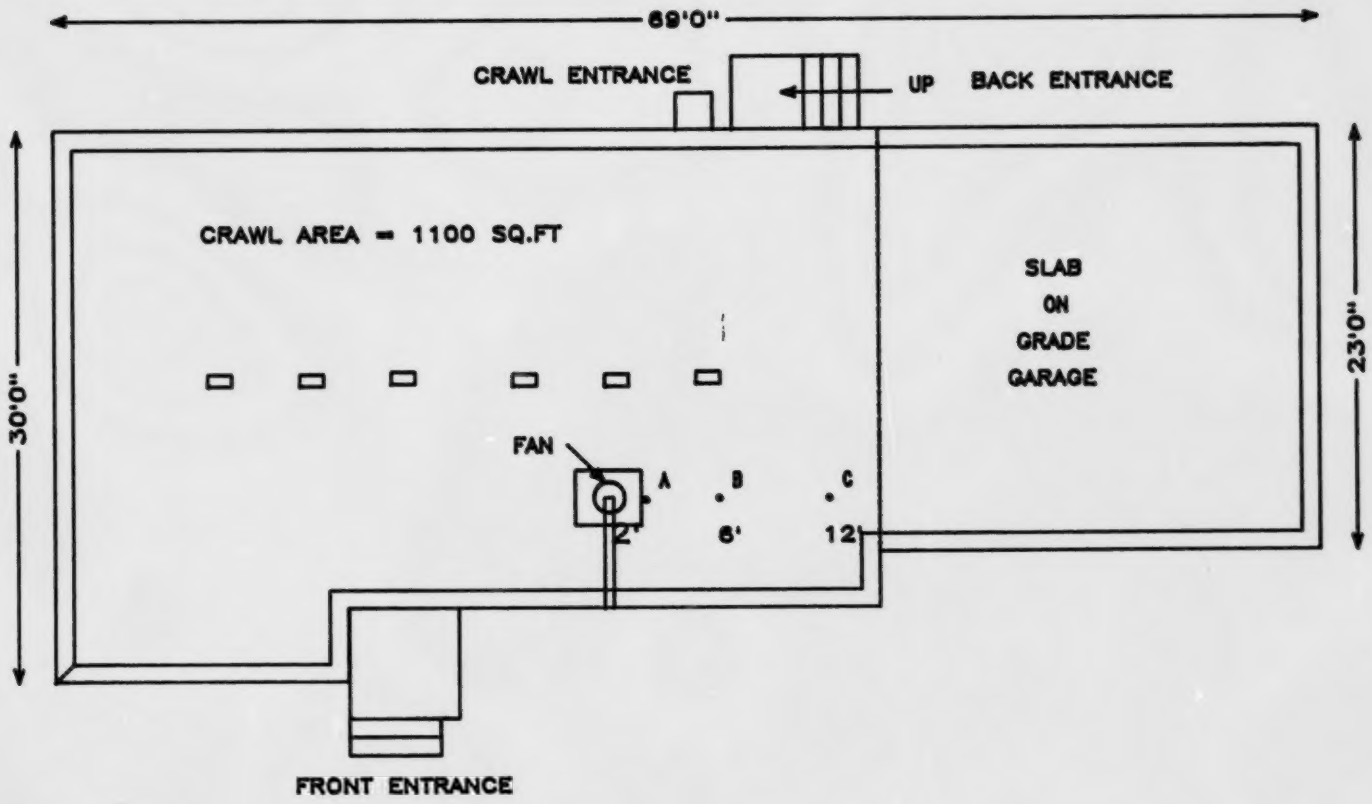

69'0"
CRAWL ENTRANCE
UP
BACK ENTRANCE
CRAWL AREA = 1100 SQ.FT
SLAB
ON
GRADE
GARAGE
FAN
A
B
C
2'
6'
12'
30'0"
23'0"
FRONT ENTRANCE

Figure 2. House DW03 crawl space layout.

The suction point(s) location and installation was to be carried out using the following scenario.

> One suction point was to be installed under the poly towards the center of the end of the crawl space by the garage following the details described in Figure 3 for a sub-poly depressurization system. This point was to be about 12 ft out from the common wall between the crawl and the slab. The fan was to be an inline centrifugal unit rated at 270 cubic feet per minute (cfm) at zero static pressure.
>
> The pressure differentials between crawl space air and sub-poly air at the suction point and at 2, 6, and 12 ft intervals from the suction point were to be measured, as well as the flow rate of the fan.
>
> If radon levels in the building were not reduced to satisfactory levels, an additional suction point was to be added near the opposite end of the crawl space from the first suction point. Measurements of the pressure differentials between crawl space air and sub-poly air at the suction points and at 2, 6, and 12 ft intervals from the suction points and of the fan flow rate were to be repeated.
>
> If radon levels were still elevated then the poly was to be sealed at the edges to the block walls and around the support posts using caulking and treated wood strips anchored with concrete nails and sealed at the sheet overlaps with a bead of polyurethane caulking.

House DW27 Mitigation Strategies

This house is unusual in that it contains a small walk-out basement area excavated out of the crawl space area. The area of this slab is 249 ft^2 and the area of exposed soil in the crawl is 1,667 ft^2. There is also a slab-on-grade garage with an area of about 900 ft^2. The soil in the crawl space was very fine and very hard with little or no permeability and there was no existing poly vapor barrier on the soil at the time of the initial evaluations. The layout of the crawl space is shown in Figure 4.

Phase 1 - Sub-Poly Depressurization (SPD)--

The first phase for this house was to depressurize the soil under polyethylene film placed on the ground as described in Figure 3. The mitigation schedule was to be as follows.

> A layer of 6 mil poly was to be placed on the ground running lengthwise between the support pillars. Shorter pieces were to be placed crosswise of the house between the pillars and at 90 degrees to the long pieces of poly. The object was to cover as much of the exposed soil as possible.
>
> Initially the poly was not to be sealed to the walls or at the edges but the seams were to be overlapped by at least one foot.
>
> The edges of the poly were to be sealed to the existing concrete slab at the crawl space entrance. Caulk was to be used as a sealant between the

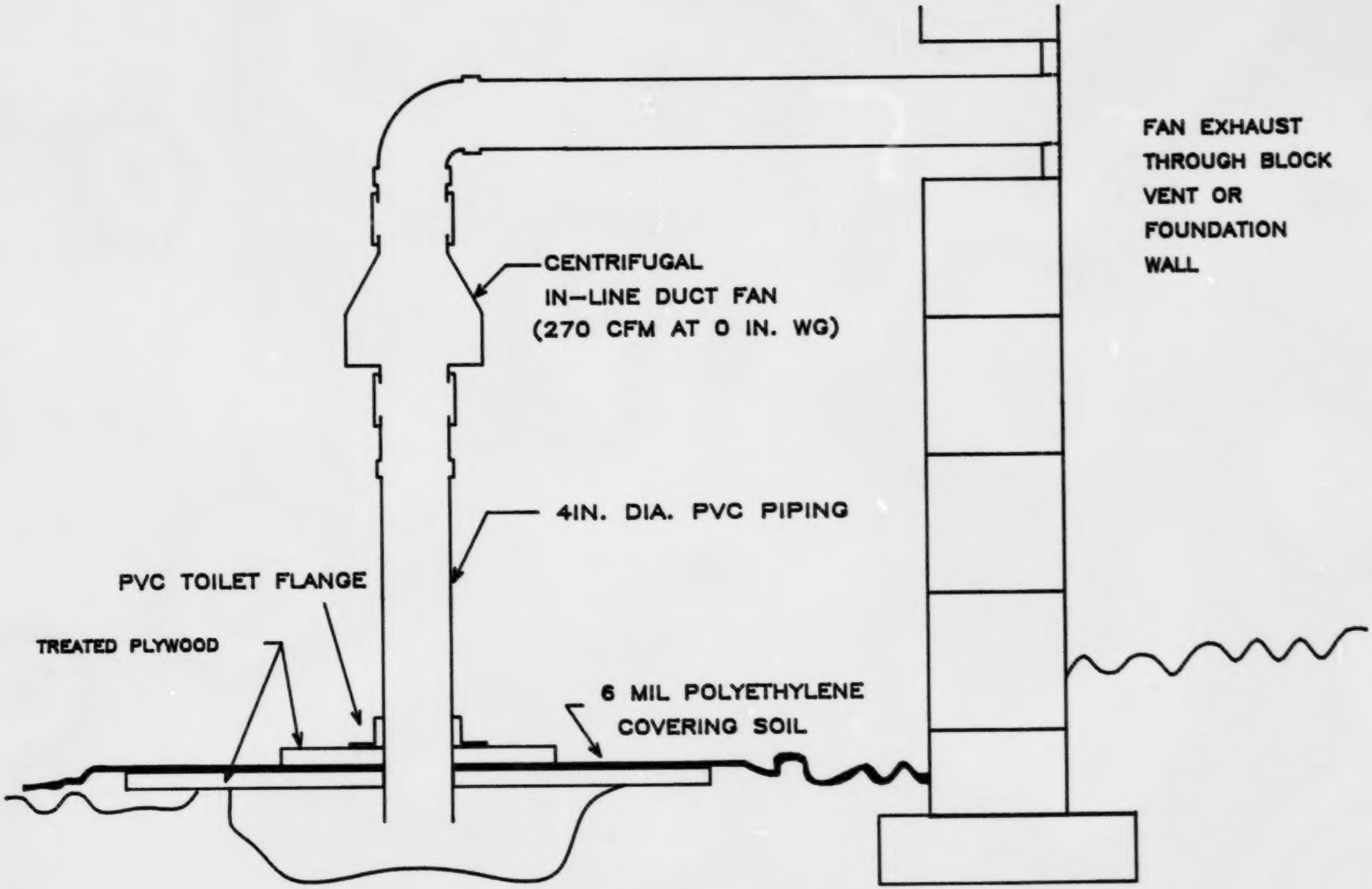

FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL
CENTRIFUGAL
IN–LINE DUCT FAN
(270 CFM AT 0 IN. WG)
4IN. DIA. PVC PIPING
PVC TOILET FLANGE
TREATED PLYWOOD
6 MIL POLYETHYLENE
COVERING SOIL

Figure 3. Sub–poly depressurization system for crawl space houses.

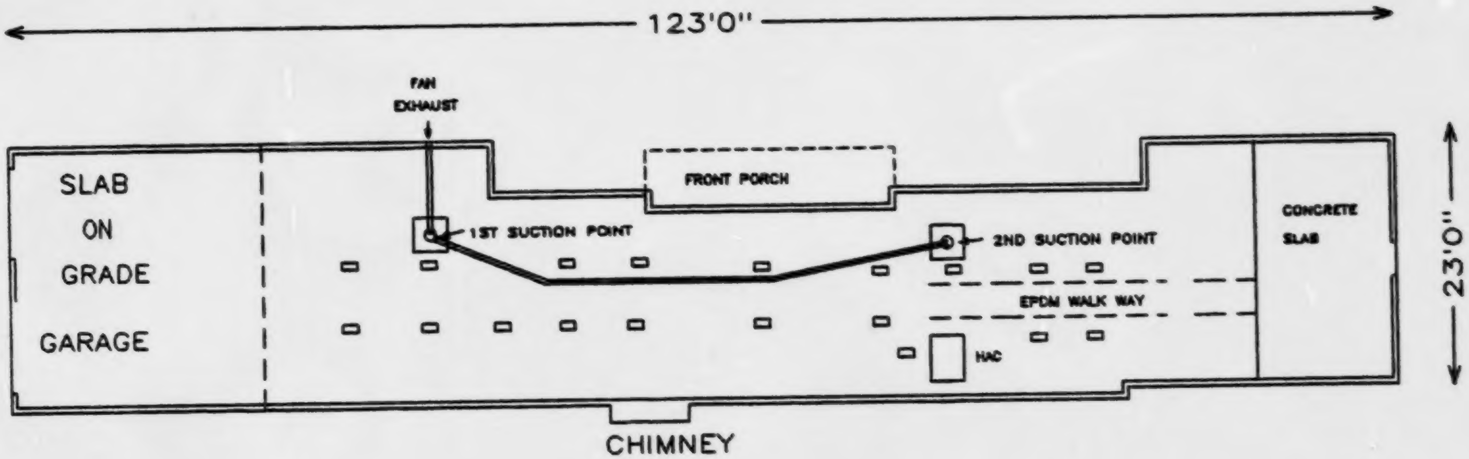

123'0"
23'0"
FAN EXHAUST
SLAB
ON
GRADE
GARAGE
1ST SUCTION POINT
FRONT PORCH
2ND SUCTION POINT
EPDM WALK WAY
HAC
CONCRETE
SLAB
CHIMNEY

Figure 4. House DW27 crawl space layout.

poly and the concrete, and the edge of the poly was to be clamped to the concrete using treated wooden strips and masonry fasteners.

A sheet of 45 mil EPDM roofing membrane was to be placed over the poly as a walkway in areas where foot traffic was likely to take place (e.g. from the door to the air handler).

A single suction point was to be installed (following the details of Figure 3.) using 4 in. diameter PVC piping and a blower (270 cfm at zero static pressure) to remove soil air from under the poly and vent it to the outside. This first suction point was to be located at the end of the building opposite the door entry into the crawl space as shown in Figure 4. A suction pit was to be excavated under the suction point as shown in Figure 3. A speed control also was to be installed on the fan so that the system could be fine tuned later if necessary.

The fan flow rate and pressure differentials between the crawl space air and under the poly at least 2, 6, and 12 ft away were to be measured.

If the pressure field developed was not adequate or the radon levels were not reduced to acceptable limits, additional suction points were to be added starting with one near the doorway end of the crawl space.

In the event additional suction points were necessary, the poly film also was to be sealed at the seams, to the walls, and to the support posts. This was to be accomplished using treated wooden strips and caulking.

Phase 2 - Isolation and Ventilation of Crawl Space (IVCS)--

This phase of the mitigation was to consist of sealing all the air leaks from the crawl space to the upstairs part of the house and to the outside except the four vents farthest from any pipes. The Phase 1 sub-poly depressurization system was to be left in operation during Phase 2.

Phase 3 - Isolation and Depressurization of Crawl Space (IDCS)--

Phase 3 was to be implemented if Phase 1 and Phase 2 did not result in acceptable levels of radon in the living areas of the house. The intent of this mitigation technique was to depressurize the crawl space and prevent crawl space air from entering the living areas of the house. The following steps were to be carried out for this phase of the mitigation.

> The four vents that were left open during Phase 2 were to be sealed using closed-cell foam board.
>
> A fan (270 cfm at zero static pressure) was to be installed to withdraw air from the crawl space and exhaust it to the outside air as shown in Figure 5. A speed control also was to be installed on the fan so that the system could be fine tuned if necessary.

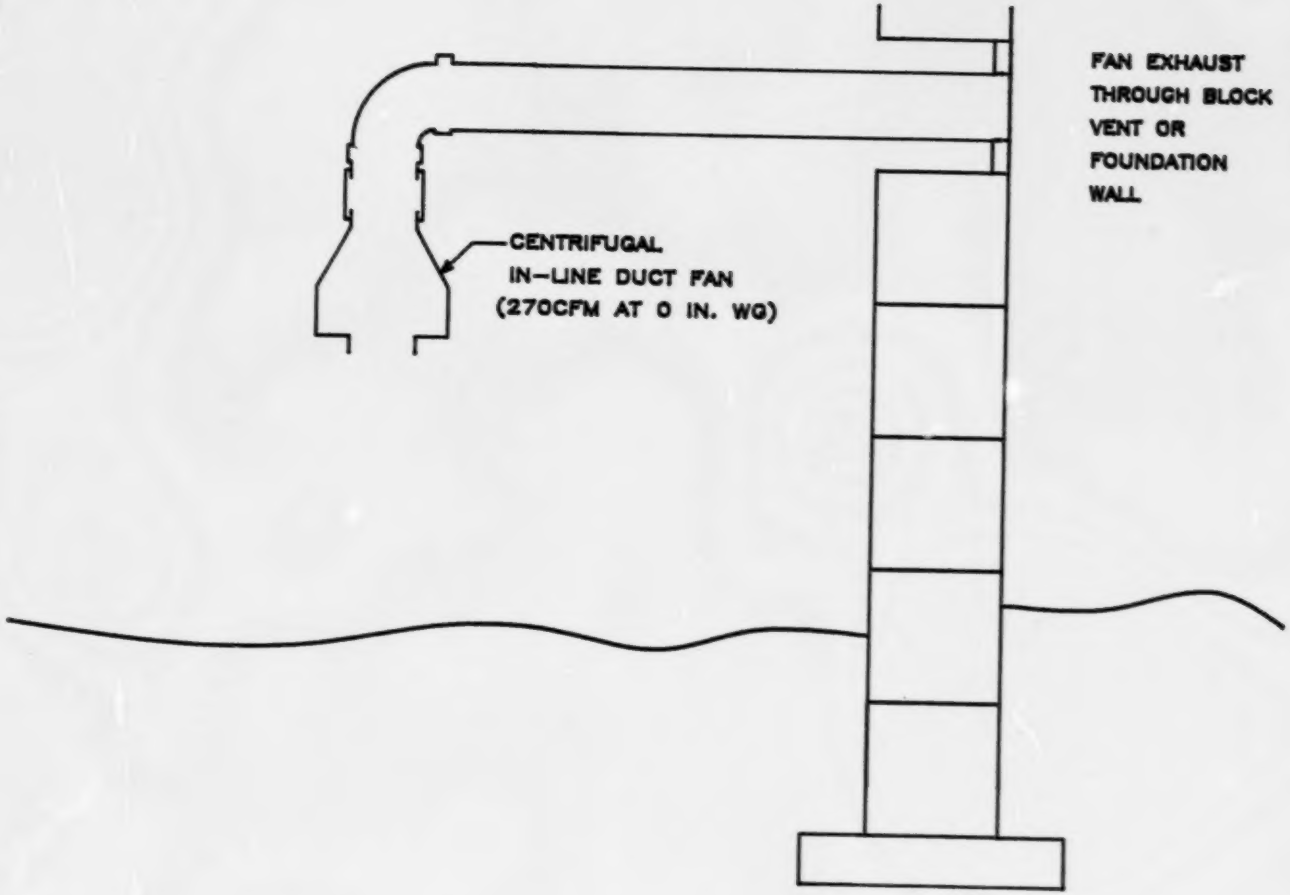

FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL
CENTRIFUGAL
IN-LINE DUCT FAN
(270CFM AT 0 IN. WG)

Figure 5. Crawl space depressurization detail.

House DW29 Mitigation Strategies

This crawl space house has approximately 2,000 ft^2 of exposed soil under the living areas. The slab-on-grade garage has a floor area of 630 ft^2 and has been converted into living space. About 70% of this was covered with existing poly installed as a moisture barrier. The central air handler supply and return ducts are located in the crawl area and have large (4 in.^{2}) openings at many locations. At the time of the initial evaluation, the clothes dryer exhaust dumped into the crawl space rather than to the outside of the house. The crawl space layout for this house is shown in Figure 6.

Phase 1 - Isolation of Crawl Space (ICS)--

The first technique was selected for this house because the floor between the living area and the crawl space was not insulated and there were HAC ducts in the crawl space to be considered. This technique also would provide an opportunity to study how well ventilation systems were connected to the crawl space air. All that was required was to seal the openings in the overhead floor using caulks and foams and to seal the HAC ducts on the negative pressure side of the distribution system. Since the vents were not to be left open during the winter there was no need to insulate the water pipes. To eliminate possible moisture buildup, the clothes dryer exhaust was to be rerouted to the outside of the house.

Phase 2 - Sub-Poly Depressurization Under Existing or New Poly (SPD)--

Phase 2 was designed to be implemented even if acceptable reductions were achieved with the Phase 1 technique. The second technique selected was to depressurize the soil under the existing poly. This method is inexpensive and simple to implement in houses that have a vapor barrier already down on the earth. Part of the goal was to determine how much sealing must be done and how many suction points are needed in order to make it work.

The soil in the crawl space was about 70% covered with a layer of poly. The remaining soil and the parts that had poly in poor condition were to be covered with new 6 mil poly film. This was to be installed in such a manner as to achieve continuous coverage with no earth exposed but with no special attempts to seal the edges of the poly to walls, support posts or at the sheet overlaps. The edges of the poly were to be overlapped by at least 12 in. One suction point was to be installed under the poly near the center of the end of the crawl space by the garage as shown in Figure 6. Installation was to be carried out following the details shown in Figure 3.

Following installation, measurements were to be made of the pressure differentials between crawl space air and sub-poly air at the suction points and at 2, 6, and 12 ft intervals from the suction point. The flow rate of the fan also was to be measured.

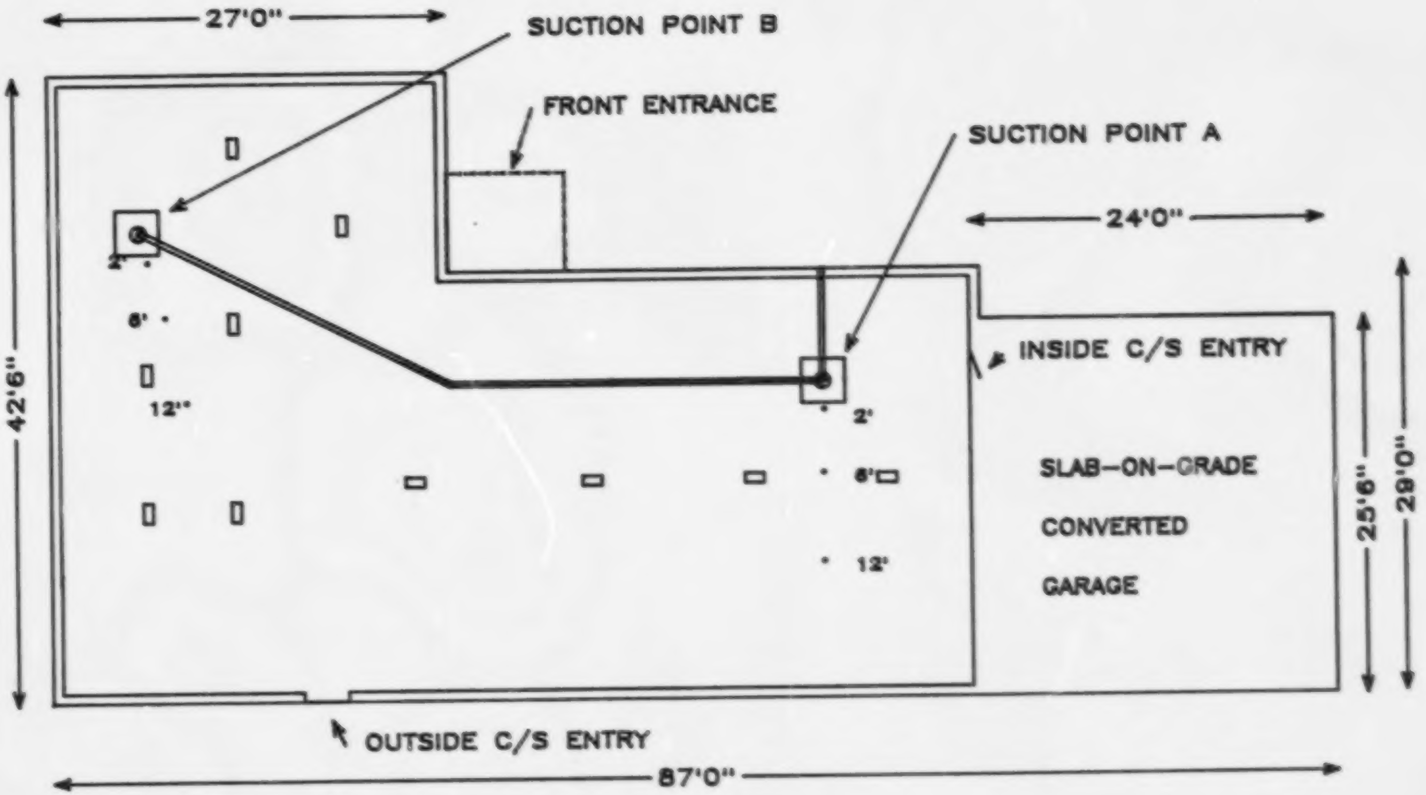

27'0"
SUCTION POINT B
FRONT ENTRANCE
SUCTION POINT A
24'0"
2'
6'
12"
INSIDE C/S ENTRY
2'
6'
12'
SLAB-ON-GRADE
CONVERTED
GARAGE
42'6"
25'6"
29'0"
OUTSIDE C/S ENTRY
87'0"

Figure 6. House DW29 crawl space layout.

If the radon levels in the living area were not reduced to satisfactory levels an additional suction point was to be added opposite the end of the crawl space where the inside entrance door was located as shown in Figure 6. Measurements of the pressure differentials and the fan flow rate were to be repeated.

If the radon levels upstairs were still elevated, the next step was to seal the edges of the poly to the block wall and around the support posts using polyurethane caulk and treated wooden strips.

House DW31 Mitigation Strategies

This house has approximately 800 ft^2 of exposed soil under the living areas with no existing poly over the soil. The slab-on-grade section of the house has an area of about 620 ft^2 and is used as the den and kitchen. The house is heated with radiant strip heaters in the baseboards and cooled with three window-mounted air conditioners. Thus, there are no HAC ducts in the crawl space. The soil in the crawl space is moderately loose compared to the other houses in this study. The layout of the crawl space is shown in Figure 7.

Phase 1 - Sub-Soil Depressurization (SSoD)--

The first technique selected for this house was to depressurize the soil by excavating suction pits in the bare earth. The details of this technique are shown in Figure 8. This method is inexpensive and simple to implement in houses that have no vapor barrier down on the earth.

Pits approximately 24 in. in diameter and 18 in. deep were to be excavated in the soil with one pit in the center of each quadrant of the crawl space as shown in Figure 7. The suction pits then were to be covered with 3 ft x 3 ft pieces of treated plywood as shown in Figure 8. Initially only two opposite corner pits (pits A and B in Figure 7) were to be connected together to a single inline centrifugal fan (270 cfm at zero static pressure). The fan exhaust was to be ducted through a block vent to the outside air.

Measurements were to be carried out of the pressure differential between crawl space air and sub-soil air at the suction points and at holes drilled in the soil at distances of 2, 6, and 12 ft intervals from the suction point. If the pressure field achieved with only two active pits was deemed inadequate then the suction pits in the remaining two quadrants (pits C and D in Figure 7) were to be connected into the fan system. As a precautionary measure, the vents into the crawl space from underneath the slab-on-grade addition were to be sealed with blocks of foil-faced foam board.

Phase 2 - Isolation and Depressurization of Crawl Space (IDCS)--

The second technique, sealing the overhead floor and depressurizing the crawl space, was selected for this house because the floor between the living space and the crawl space was not insulated and there were no HAC ducts in the

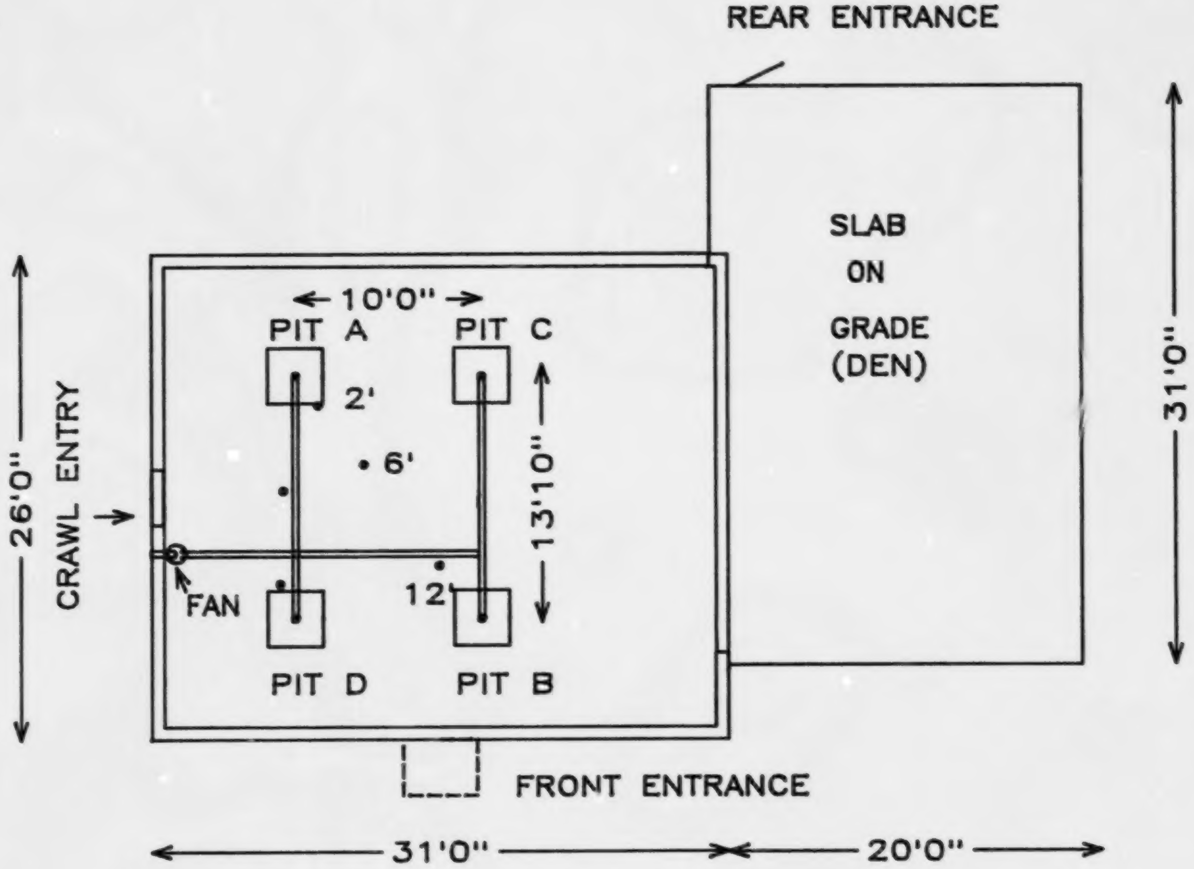

REAR ENTRANCE
SLAB
ON
GRADE
(DEN)
31'0"
10'0"
PIT A
PIT C
2'
6'
13'10"
26'0"
CRAWL ENTRY
FAN
12'
PIT D
PIT B
FRONT ENTRANCE
31'0"
20'0"

Figure 7. House DW31 crawl space layout.

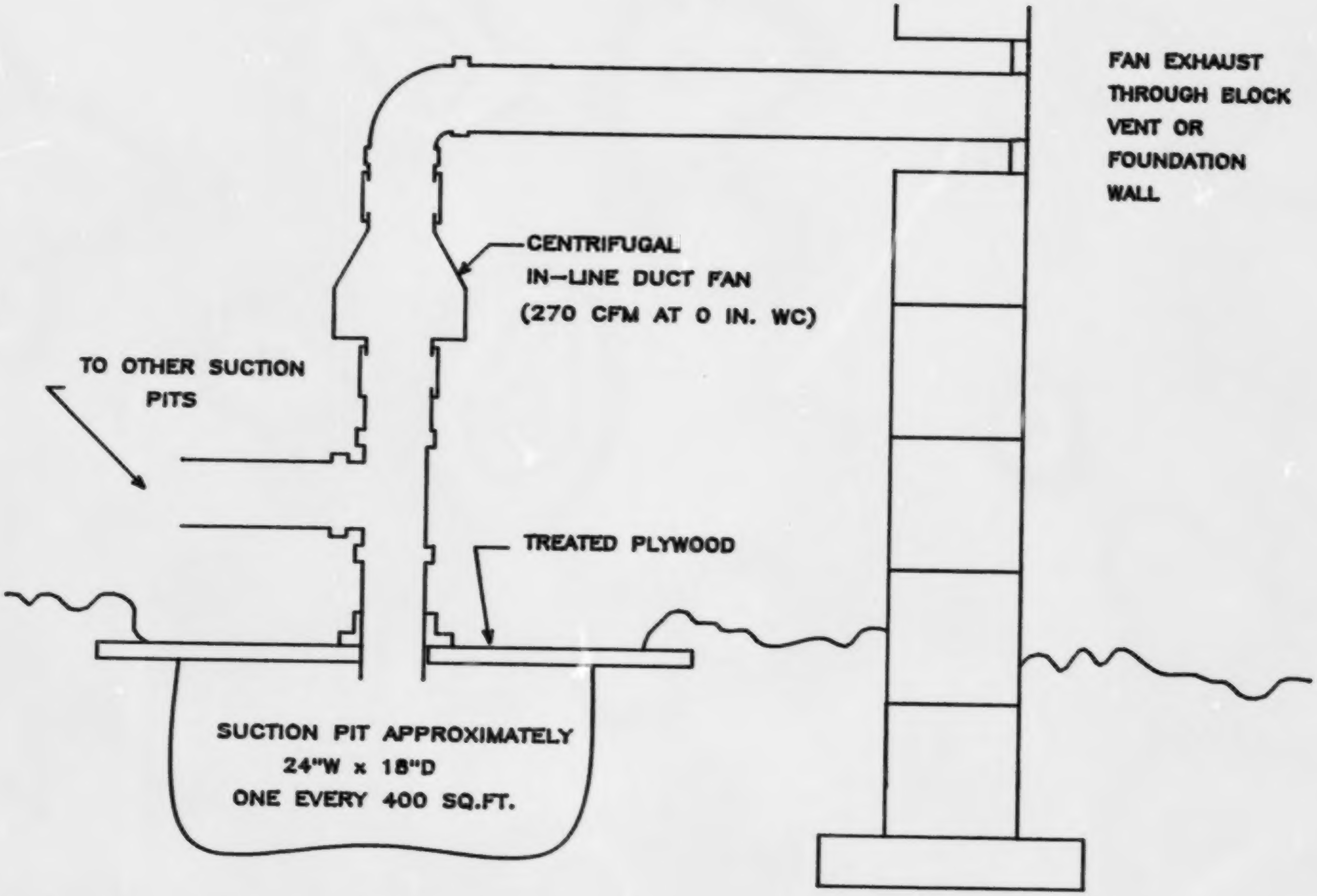

FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL
CENTRIFUGAL
IN–LINE DUCT FAN
(270 CFM AT 0 IN. WC)
TO OTHER SUCTION
PITS
TREATED PLYWOOD
SUCTION PIT APPROXIMATELY
24"W x 18"D
ONE EVERY 400 SQ.FT.

Figure 8. Sub–soil depressurization system detail.

crawl space to be considered. Crawl space depressurization may also take care of depressurizing the soil beneath the slab-on-grade addition. This mitigation phase could be accomplished easily using the fan system installed during Phase 1. All that was required was to disconnect the ducting at the inlet to the fan. A variable speed control was to be used on the fan so that the flow could be adjusted to provide low radon levels using a minimum amount of exhaust air. Details of this procedure are shown in Figure 5.

The following locations were to be sealed with closed-cell expanding foam and polyurethane caulking: water supply and wastelines (especially tub and toilet), and any other large openings between the crawl space air and the house air. All vents to the outside of the crawl space were to be tightly sealed from the inside using foil faced foam board and caulking. Any other large openings from the crawl space air to the outside also were to be sealed as tightly as possible.

House DW60 Mitigation Strategies

This house has no HAC ducts in the crawl space and the soil area in the crawl (approximately 900 ft^2) is only partially (35%) covered with existing poly in poor condition. The slab-on-grade garage has been converted into a laundry/storage room with an area of about 300 ft^2. The layout of the crawl space is shown in Figure 9.

Phase 1 - Isolation and Ventilation of Crawl Space (IVCS)--

The first technique was considered for this house because the floor between the living space and the crawl space was already insulated, there were no HAC ducts in the crawl space to be considered, and the crawl already had vents. All that was required was to seal the openings in the overhead floor using caulks and foams, to insulate the water pipes using closed-cell pipe insulation, and to leave open a number of vents during the winter months.

The following locations in the floor or structure were to be sealed.

- Around termite shield and block cracks with polyurethane caulk
- Around pipe entries (toilet and tub) with caulk and foam
- Around access door to tub with caulk
- The vent into garage was to be sealed with foam board and caulk
- Around the washer drain and the electric wires to the left of the washer
- Any other large easily accessible openings between the crawl space air and the upstairs air were to be sealed.

The three sewer drain traps were to be wrapped with a minimum R10 insulation.

During testing, two vents on opposite walls of the crawl space were to be left open. These vents were to be selected to minimize the possibility of freeze damage to water pipes.

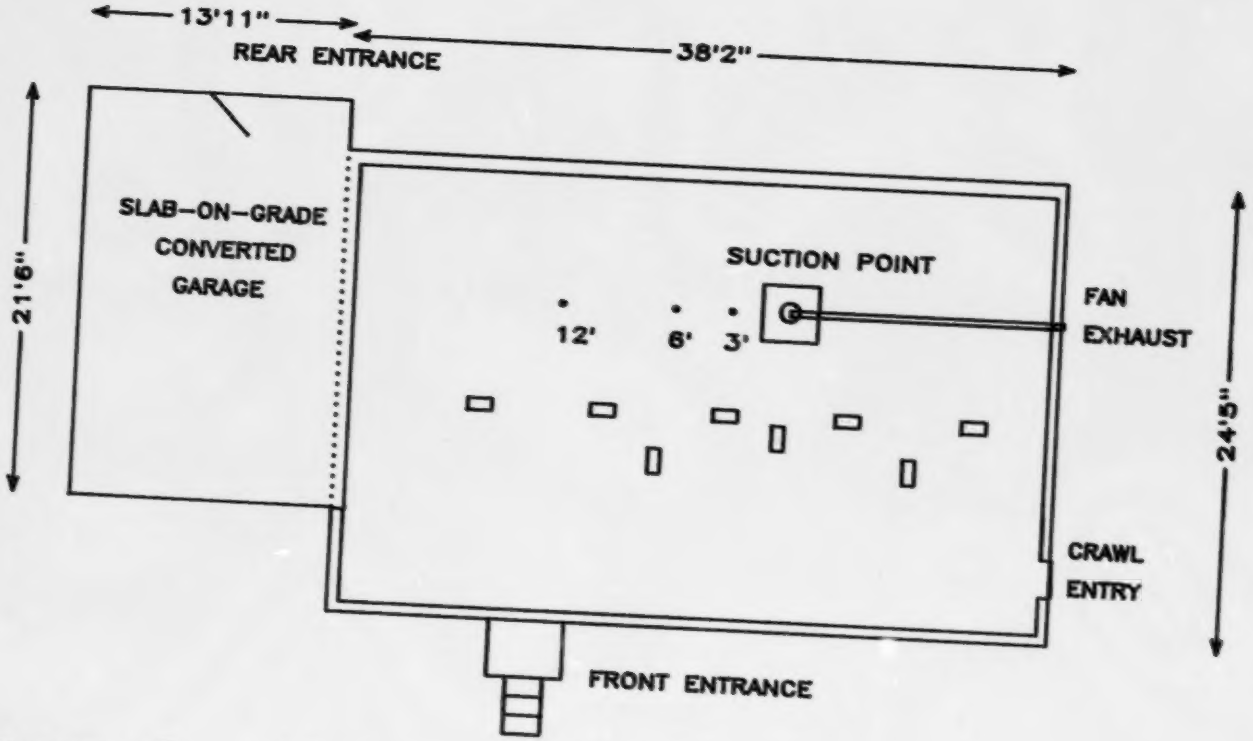

13'11"
REAR ENTRANCE
38'2"
21'6"
SLAB-ON-GRADE
CONVERTED
GARAGE
SUCTION POINT
12'
6'
3'
FAN
EXHAUST
24'5"
CRAWL
ENTRY
FRONT ENTRANCE

Figure 9. House DW60 crawl space layout.

Phase 2 - Sub-Poly Depressurization (SPD)--

The second technique selected was to depressurize the soil under the existing poly. The existing soil in the crawl space was less than 35% covered with poly and only about half of this was in good condition. Preliminary experiments, carried out during the diagnostic visit, showed good pressure field development 12 ft from the suction point. The remaining soil and the areas that had poly in poor condition were to be covered with new 6 mil poly film.

The location and installation of the suction point(s) was to be carried out using the following scenario.

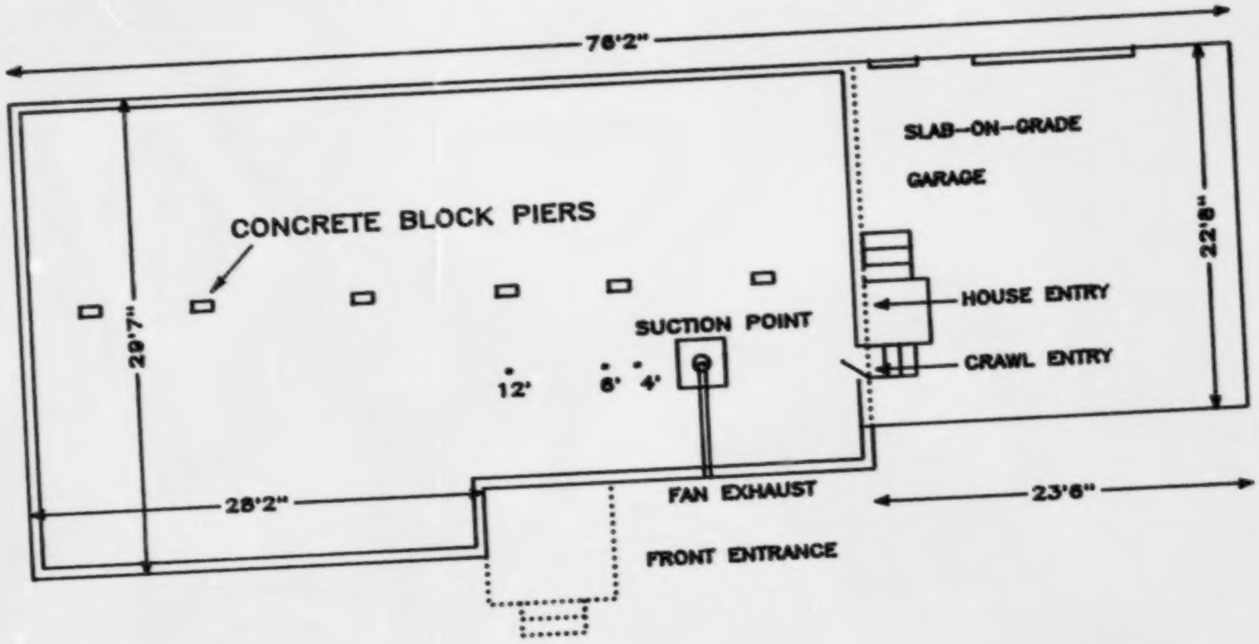
> One suction point was to be installed under the poly towards the center of the end of the crawl space by the den. This installation was to be carried out following the details describes in Figure 3 for a sub-poly depressurization system. This point was to be about 12 ft out from the common wall between the crawl and the slab as shown in Figure 9. The pressure differentials between crawl space air and sub-poly air at the suction point and at 2, 6, and 12 ft intervals from the suction point were to be measured, as well as the flow rate of the fan.
>
> If radon levels in the building were not reduced to satisfactory levels, an additional suction point was to be added near the opposite end of the crawl space from the first suction point. Measurements of the pressure differentials between crawl space air and sub-poly air at the suction points and at 2, 6, and 12 ft intervals from the suction points and of the fan flow rate were to be repeated.
>
> If radon levels were still elevated then the poly was to be sealed at the edges to the block walls and around the support posts using caulking and treated wood strips anchored with concrete nails and sealed at the sheet overlaps with a bead of polyurethane caulking.

House DW66 Mitigation Strategies

This house has approximately 1500 ft^2 of exposed soil under the living areas. The soil was covered with existing poly sheeting to about 70%, but the condition of the material was fairly poor. The slab-on-grade garage has an area of about 600 ft^2. The house has a central air handling system with all ductwork located in the crawl space. The crawl space layout is described in Figure 10.

Phase 1 - Isolation of Crawl Space (ICS)--

The first technique, sealing the openings between the crawl space and the living area, was selected for this house because the floor between the living space and the crawl space was not insulated and there were HAC ducts in the crawl space to be considered. Also, by applying this technique, the degree of



78'2"
SLAB-ON-GRADE
GARAGE
CONCRETE BLOCK PIERS
22'8"
HOUSE ENTRY
SUCTION POINT
CRAWL ENTRY
29'7"
12'
6'
4'
28'2"
FAN EXHAUST
23'6"
FRONT ENTRANCE

Figure 10. House DW66 crawl space layout.

communication between the ventilation system and the crawl space air could be studied. All that was required was to seal the openings in the overhead floor using caulks and foams and to seal the HAC ducts on the negative pressure side of the distribution system. Since the vents were not to be left open during the winter, there was no need to insulate the water pipes.

Phase 2 - Sub-Poly Depressurization (SPD)--

The second technique selected for this house was to depressurize the soil under the existing poly. The existing soil in the crawl space was about 50% covered with poly but even this was not in good condition. The remaining soil and the parts that had poly in poor condition were to be covered with new 6 mil poly film.

The location and installation of the suction point(s) were to be carried out using the following scenario.

> One suction point was to be installed under the poly towards the center of the end of the crawl space by the garage as shown in Figure 10. The installation details are described in Figure 3 for a sub-poly depressurization system. This point was to be about 12 ft out from the common wall between the crawl and the slab.
> The pressure differentials between crawl space air and sub-poly air at the suction point and at 2, 6, and 12 ft intervals from the suction point were to be measured, as well as the flow rate of the fan.
>
> If radon levels in the building were not reduced to satisfactory levels, an additional suction point was to be added near the opposite end of the crawl space from the first suction point. Measurements of the pressure differentials between crawl space air and sub-poly air at the suction points and at 2, 6, and 12 ft intervals from the suction points and of the fan flow rate were to be repeated.
>
> If radon levels were still elevated, then the poly was to be sealed at the edges to the block walls and around the support posts using caulking and treated wood strips anchored with concrete nails and sealed at the sheet overlaps with a bead of polyurethane caulking.

House DW82 Mitigation Strategies

The configuration of the crawl space under this house is shown in Figure 11. There are no HAC ducts in the crawl space and no existing poly over the soil. The house is heated with radiant strip heaters in the ceiling and baseboards and cooled with window units. The exposed soil area is approximately 1600 ft^2, with some areas inaccessible due to the addition of a den upstairs almost touching the soil below.

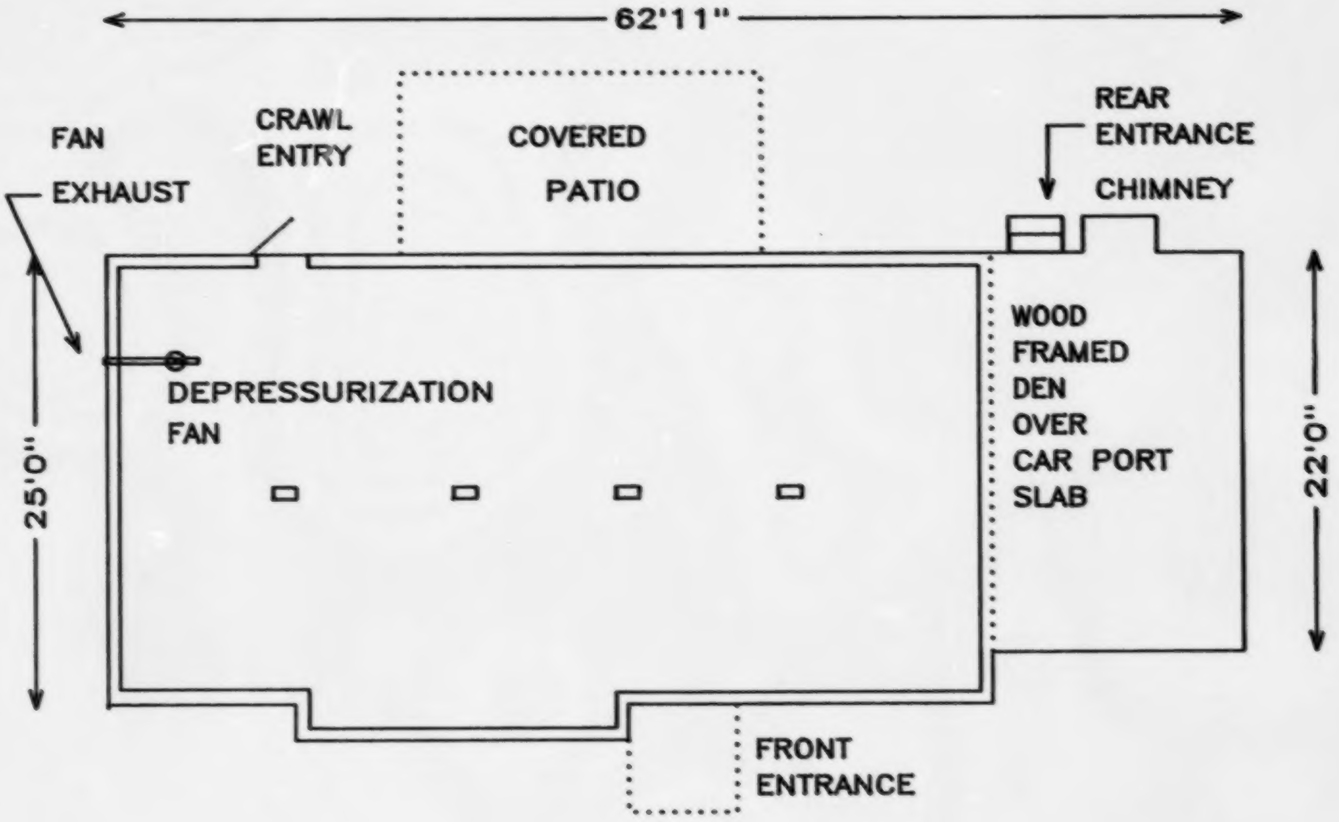

62'11"
FAN
EXHAUST
CRAWL
ENTRY
COVERED
PATIO
REAR
ENTRANCE
CHIMNEY
WOOD
FRAMED
DEN
OVER
CAR PORT
SLAB
DEPRESSURIZATION
FAN
25'0"
22'0"
FRONT
ENTRANCE

Figure 11. House DW82 crawl space layout.

Phase 1 - Isolation and Pressurization of Crawl Space (IPCS)--

The first technique of sealing and pressurizing (and/or ventilating) the crawl space will be carried out through the use of a commercially available device (Model 300, Current Indoor Air Systems, Inc., Boulder, CO). This system, sometimes referred to as the "Kyle Lefkoff device", consists of a blower (270 cfm at zero static pressure) that blows air into the crawl space, a concentric pipe around the inlet pipe that allows air to vent out of the crawl space while preheating the incoming air, and a draft hood to aid in the ventilation process. The manufacturer refers to it as a pressurization device and has had several installations with good success. It is unknown how much this success was due to dilution and how much to pressurization.

This technique was selected for this house because the floor between the living space and the crawl space was not insulated, there were no HAC ducts in the crawl space to be considered, the soil was not porous enough to use the bare earth suction pit method, and there was no existing poly film. Implementation of the crawl space pressurization/dilution mitigation system was to proceed according to the following steps.

> The openings between the crawl space and the living areas were to be sealed using polyurethane calks and closed-cell expanding foams. Particular attention was to be paid to sealing around the water supply and waste pipes (e.g. tub and toilet).
>
> All vents and openings from the crawl space to the outside were to be closed with foam-board and caulking.
>
> The Kyle Lefkoff system was to be installed according to the manufacturers instructions. Details of this mitigation technique are shown in Figure 12.

During the pre- and post-mitigation testing periods, the following procedure was to be followed.

> The fan flow rate and the pressure differential between crawl space and outside air was to be measured. The effect of dilution was to be estimated based on these measurements.
>
> The crawl space, house and ambient temperatures during pre and post mitigation were to be measured and recorded using a data-logger.

Phase 2 - Isolation and Depressurization of Crawl Space (IDCS)--

The second technique selected for this house was to depressurize the crawl space and prevent entry of crawl space air into the living areas. This was a good candidate building because the overhead floor was uninsulated and there were no ducts in the crawl to seal. If the air leaks to the outside could be sealed well enough, then freezing of pipes in the crawl space was not considered to be a problem. The fan door test carried out in October on the crawl space indicates that a fan of about 300 cfm should put a ΔP of about 0.008 in.WC on the crawl space with no tightening.

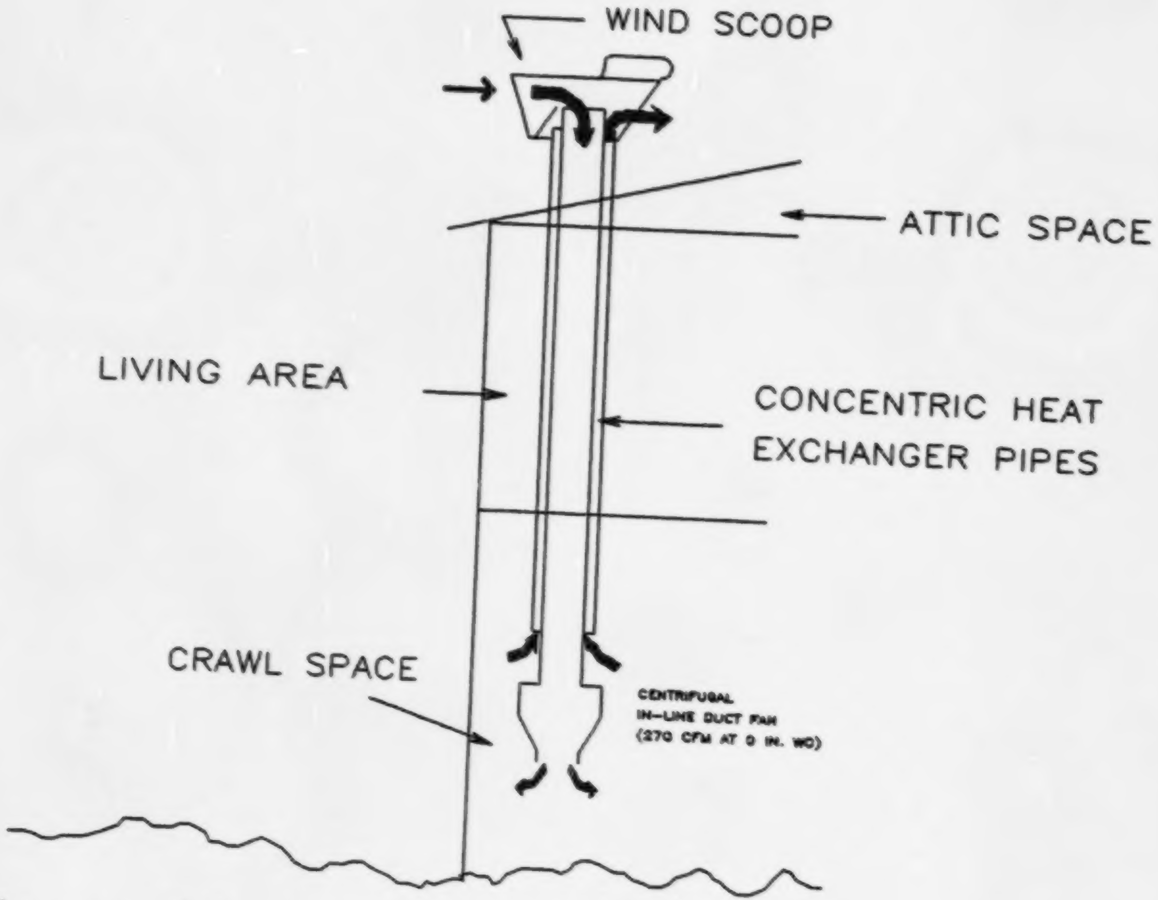

WIND SCOOP
ATTIC SPACE
LIVING AREA
CONCENTRIC HEAT EXCHANGER PIPES
CRAWL SPACE
CENTRIFUGAL IN-LINE DUCT FAN (270 CFM AT 0 IN. WG)

Figure 12. Crawl space pressurization system.

This mitigation phase was to proceed as follows.

A blower (270 cfm at zero static pressure) was to be installed so that air is pulled from the crawl space and vented to the outdoors. This was to be done using an existing vent for the exhaust port as shown in Figure 5. A variable speed control was to be used on the fan so that the flow can be adjusted to provide low radon levels using a minimum amount of exhaust air.

Testing with smoke sticks and pressure gauges was to be carried out to make sure that air was flowing from the house into the crawl space. Measurements of the fan flow rate and pressure differential between crawl space air and outside air also was to be carried out.

House DW84 Mitigation Strategies

This house has approximately 1500 ft^2 of exposed soil under the living areas with no poly covering the soil. The area of the slab-on-grade attached garage is about 500 ft^2. The HAC ducts located in the crawl space were, in some locations, lying directly on the soil. The soil was relatively hard but contained large desiccation cracks up to 0.5 in. wide over most of the soil area. The layout of the crawl space is shown in Figure 13.

Phase 1 - Sub-Soil Depressurization (SSoD)--

The first technique selected for this house was to depressurize the soil by excavating suction pits in the bare earth. The details of this technique are shown in Figure 8. This method is inexpensive and simple to implement in houses that have no vapor barrier down on the earth. This installation would also provide a comparison to the results achieved in DW 82 where the soil characteristics are entirely different. It would also provide information about the role played by the soil cracks in radon emission rates.

Pits approximately 24 in. in diameter and 18 in. deep were to be excavated in the soil with one pit in the center of each quadrant of the crawl space as shown in Figure 13. The suction pits then were to be covered with 3 ft x 3 ft pieces of treated plywood as shown in Figure 8. Initially only two opposite corner pits (pits A and B in Figure 13) were to be connected together to a single inline centrifugal fan (270 cfm at zero static pressure). The fan exhaust was to be ducted through a block vent to the outside air.

Measurements were to be carried out of the pressure differentials between crawl space air and sub-soil air at the suction points and at holes drilled in the soil at distances of 2, 6, and 12 ft intervals from the suction point. If the pressure field achieved with only two active pits was deemed inadequate then the suction pits in the remaining two quadrants were to be connected into the fan system. As a precautionary measure the vents into the crawl space from underneath the slab-on-grade addition were to be sealed with blocks of foil-faced foam board.

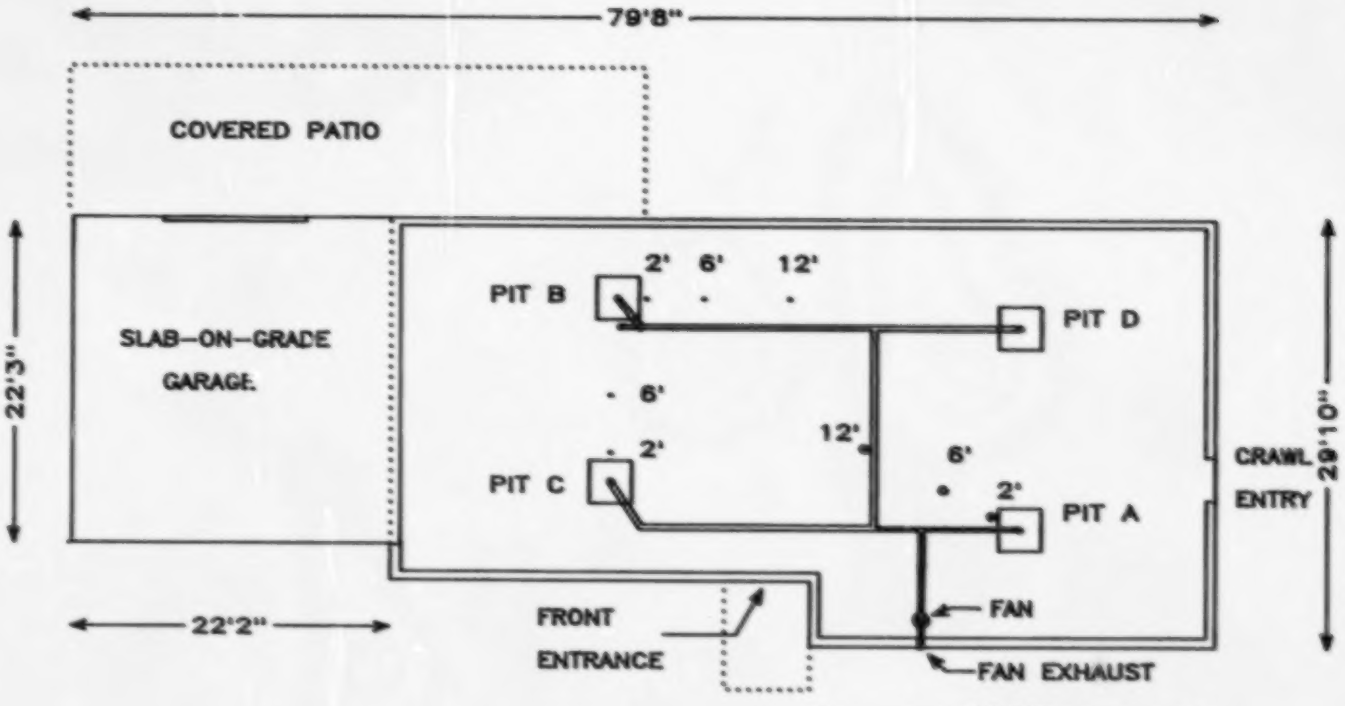

79'8"
COVERED PATIO
SLAB-ON-GRADE
GARAGE
22'3"
22'2"
PIT B
PIT C
PIT D
PIT A
2'
6'
12'
6'
2'
12'
6'
2'
CRAWL
ENTRY
29'10"
FRONT
ENTRANCE
FAN
FAN EXHAUST
28'0"

Figure 13. House DW84 crawl space layout.

Phase 2 - Sub-Poly (membrane) Depressurization (SPD)--

The second phase mitigation technique selected for this house was to place a layer of ethylene-propylene-diene monomer (EPDM) film on the earth in the crawl space and use the suction system from Phase 1 to depressurize the soil. This technique generally was to follow that described in Figure 3 above except that the poly was to be replaced with the EPDM material.

This phase of the mitigation was to proceed as follows.

A 45 mil thickness layer of EPDM roofing membrane was to be installed on the earth and around the suction pipes from Phase 1. No attempt was to be made to seal the membrane to the walls of the crawl space but at least an 8 in. overlap was to be provided at the edges of the EPDM sheets. Also the EPDM was to be sealed to the covers on the suction pits.

Measurements were to be made of the pressure differential between crawl space air and sub-EPDM air at suction points and at 2, 6, and 12 ft intervals from the suction point. The flow rate of the fan also was to be measured. If pressure distribution under the membrane was found to be inadequate, then strips of drainage material were to be added under the EPDM.

If the radon levels in the living areas were still elevated, then the EPDM was to be sealed at the edges to the block wall and around the support posts using mastic and treated wooden strips anchored to the concrete blocks. Also, the sheet overlaps were to be sealed with mastic.

House DW90 Mitigation Strategies

This house has approximately 1100 ft^2 of exposed soil in the crawl space. The slab-on-grade garage has an area of about 300 ft^2. There are no HAC ducts in the crawl and the soil was 80% to 90% covered with poly in fair condition. The layout of the crawl space is shown in Figure 14.

Phase 1 - Isolation and Ventilation of Crawl Space (IVCS)--

The first technique was considered for this house because the floor between the living space and the crawl space was already insulated, there were no HAC ducts in the crawl space to be considered, and the crawl already had vents. All that was required was to seal the openings in the overhead floor using caulks and foams, to insulate the water pipes using closed-cell pipe insulation, and to leave open a number of vents during the winter months.

The following locations in the floor or structure were to be sealed.

- Around pipe entries (toilet and tub) with caulk and foam
- Around access door to tub with caulk
- The vent into garage was to be sealed with foam board and caulk
- Any other large easily accessible openings between the crawl space air and the upstairs air were to be sealed.

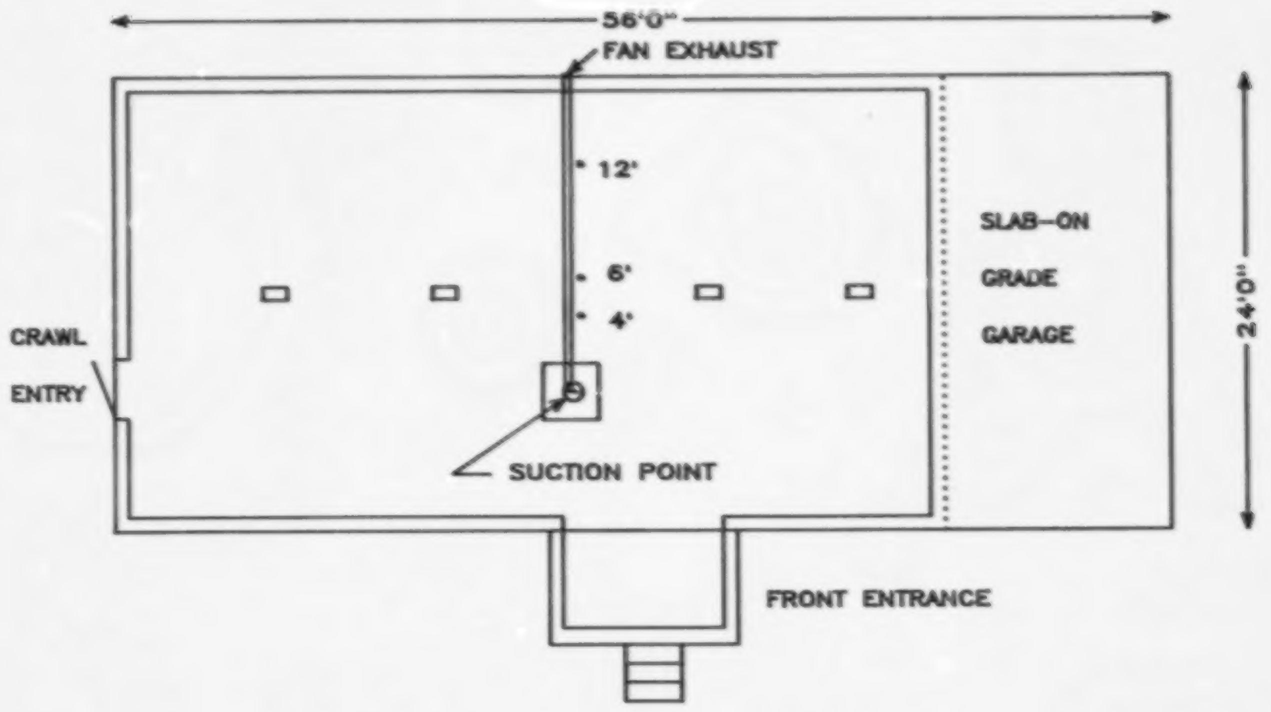

56'0"
FAN EXHAUST
12'
6'
4'
CRAWL
ENTRY
SUCTION POINT
SLAB-ON
GRADE
GARAGE
24'0"
FRONT ENTRANCE

Figure 14. House DW90 crawl space layout.

The sewer drain traps were to be wrapped with a minimum R10 insulation.

During testing, two vents on opposite walls of the crawl space were to be left open. These vents were to be selected to minimize the possibility of freeze damage to water pipes.

Phase 2 - Sub-Poly Depressurization (SPD)--

The second technique selected for this house was to depressurize the soil under the existing poly as described in Figure 3 above. The existing soil in the crawl space was about 90% covered with poly. The remaining soil and the parts that had poly in poor condition were to be covered with new 6 mil poly film, making no attempts to seal the edges of the poly to the walls or the support piers. The sheets of poly were to have overlaps of at least 12 in..

The location and installation of the suction point(s) was to be carried out using the following scenario.

> One suction point was to be installed under the poly towards the center of the end of the crawl space by the garage. This point was to be about 12 ft out from the common wall between the crawl and the slab as shown in Figure 14.
>
> The pressure differentials between crawl space air and sub-poly air at the suction point and at 2, 6, and 12 ft intervals from the suction point were to be measured, as well as the flow rate of the fan.
>
> If radon levels in the building were not reduced to satisfactory levels, an additional suction point was to be added near the opposite end of the crawl space from the first suction point. Measurements of the pressure differentials between crawl space air and sub-poly air at the suction points and at 2, 6, and 12 ft intervals from the suction points and of the fan flow rate were to be repeated.
>
> If radon levels were still elevated, then the poly was to be sealed at the edges to the block walls and around the support posts using caulking and treated wood strips anchored with concrete nails and sealed at the sheet overlaps with a bead of polyurethane caulking.

BASEMENT HOUSES CONVERTED FROM CRAWL SPACES

House DW43 Mitigation Strategies

This house has a basement excavated out of an existing crawl space. There is also an existing interior block wall that forms a concrete capped shelf around 80 percent of the basement. The area of the floor slab is approximately 600 ft^2 and the area of the shelf is about 300 ft^2. The layout of the basement of this house is shown in Figure 15.

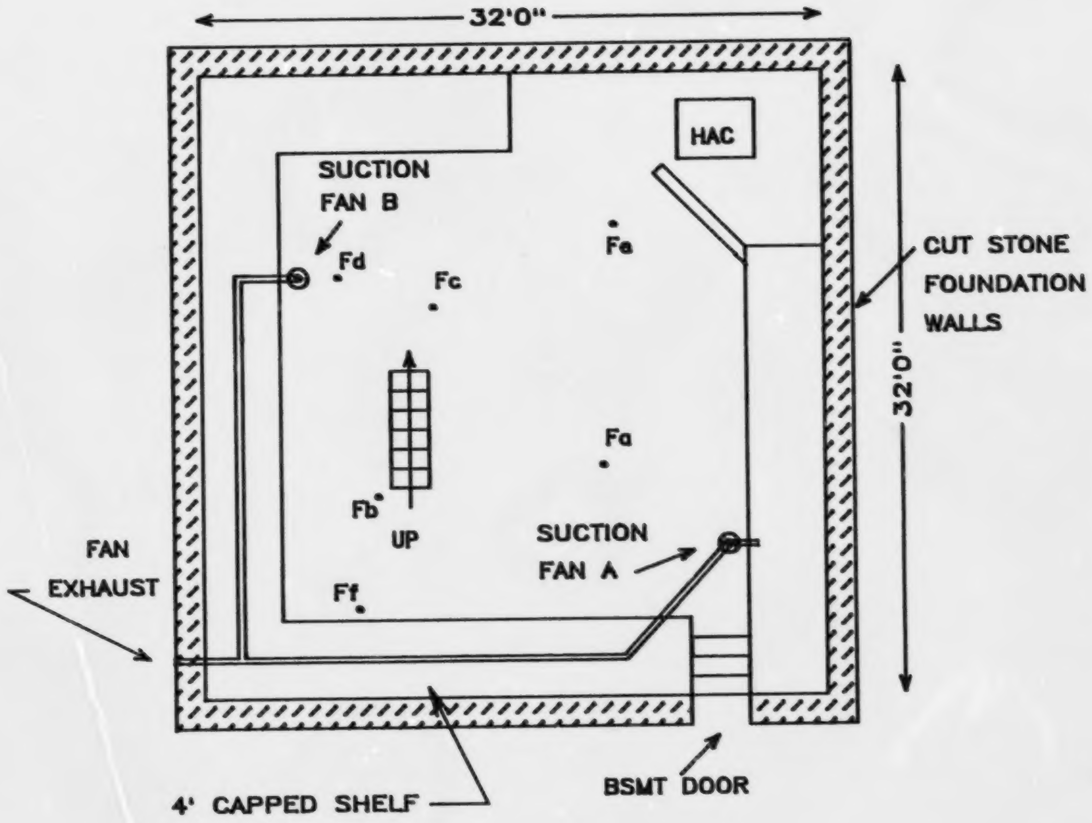

32'0"
32'0"
HAC
SUCTION FAN B
Fd
Fc
Fe
Fa
Fb
UP
Ff
SUCTION FAN A
FAN EXHAUST
CUT STONE FOUNDATION WALLS
4' CAPPED SHELF
BSMT DOOR

Figure 15. House DW43 basement plan.

Phase 1 and 2 - Sub-Slab Depressurization with Narrow/Wide Pit (SSD-N-W)--

The first technique considered for this house was depressurizing the soil using first a narrow, deep (4 in. diameter x 28 in. deep) pit, then a broad (24 in. diameter x 10 in. deep) pit, and finally a combination suction pit. Because of the poor communication observed during the diagnostic tests, two suction holes were to be installed at opposite corners of the basement slab. The details of this mitigation approach are shown in Figure 16 (minus the block wall suction tap) and the locations of the suction holes are shown in Figure 15.

Sub-slab suction was considered although tests showed poor sub-slab communication. The effects of pit size and shape upon the sub-slab communication are not well known for those cases in which there is little or no aggregate under the slab. These parameters are thought to be of little significance when communication under the slab is good to excellent. It was speculated that by varying these parameters a relationship between pit size or shape and system effectiveness could be identified. Hopefully, the results of these tests would lead to a better understanding of where and when this type of mitigation system can be applied for houses with poor sub-slab communication.

In implementing this phase of the mitigation, both suction holes were to be installed at the same time, but their effectiveness was to be tested separately to determine whether one size or shape would result in a more extensive pressure field under the slab. Only one hole was to be left open at a given time. Two blowers (270 cfm at zero static pressure) with a variable speed control were to be used to provide suction power.

After installing the suction holes and fans, pressure field measurements were to be carried out under the slab, in the block wall, and under the shelf slab between the interior block wall and the foundation wall. These measurements were to be carried out with first one fan on and one off, then the reverse situation, and then with both fans on. Measurements of the fan flow rates also were to be carried out.

Following the tests of pressure field extension versus pit shape, the sub-slab systems were to be operated in a combined configuration to evaluate the reductions achieved in the radon levels in the basement.

Phase 3 - Sub-Slab Plus Block Wall Depressurization (SSBWD)--

The third phase selected for this house, in the event that Phases 1 and 2 did not result in adequate reductions of the radon levels, was to use the fan systems in the first two phases to apply suction to the interior block walls as also shown in Figure 16. This was to be carried out by tapping into the interior block walls adjacent to the suction holes used in Phases I and 2. Following the installation the measurements of pressure fields and fan flow rates were to be repeated as well as the long tern effects upon the basement radon levels.

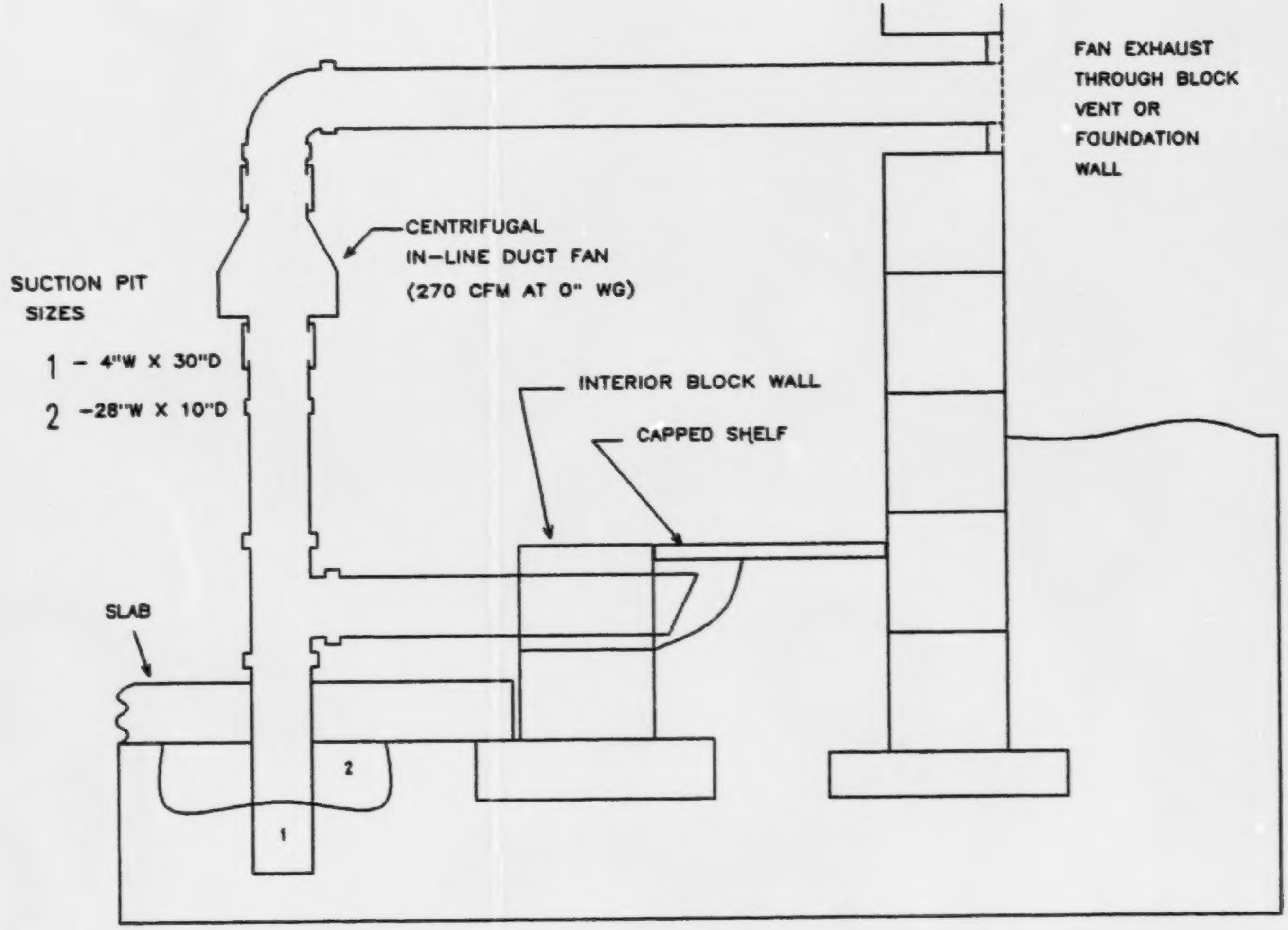

FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL
CENTRIFUGAL
IN-LINE DUCT FAN
(270 CFM AT 0" WG)
SUCTION PIT
SIZES
1 - 4"W X 30"D
2 -28"W X 10"D
INTERIOR BLOCK WALL
CAPPED SHELF
SLAB
2
1

Figure 16. Sub-slab plus block wall depressurization with varying suction pit shapes.

House DW58 Mitigation Strategies

This house has a basement excavated out of an existing crawl space. Only a small portion of the basement floor was covered by a concrete slab. The remaining part of the basement was composed of earthen floor with a dirt wall at one end of the excavated portion. Approximately one third of the area under the house was left as a crawl space with no excavated soil. The soil throughout the basement and adjoining crawl space was very hard and impermeable and did not lend itself to simple depressurization control methods. Surface soil emanation was probably the dominant entry mechanism although there were numerous large openings in the concrete block foundation walls that probably also acted as radon entry points. The layout of the basement/crawl space areas is shown in Figure 17.

Because of the condition of the basement, no low-cost mitigation options were available for this house. Therefore, the costs for the Phase 1 mitigation system were expected to be more in line with those of the Phase 3 options for the other houses of this category.

Phase 1 - Sub-Slab Depressurization with Wide Pit (SSD-W)--

For the reasons described above, the first method selected for this house was to seal the earth with a barrier on top of a drainage board so that the soil surface can be depressurized. The installation was to proceed according to the details shown in Figures 18 and 19 as follows.

> First, a layer of crushed stone 3 in. thick was to be placed on the floor. A durable plastic film was to be placed over the aggregate, and a 3 in. thick concrete slab was to be poured on top. In pouring the slab, a piece of 4 in. diameter PVC pipe was to be cast in the concrete. This pipe was to rise vertically from the floor in one corner of the basement near the block wall so that the block wall and the earth bank could easily be reached from this single hole. A blower (270 cfm at zero static pressure) was to be used to remove soil air from under the new slab and vent it to the outside as shown in Figure 18.
>
> For the unexcavated portion of the basement and the earth wall, drainage board was to be used to cover the soil with a network of 8 in. to 12 in. wide strips. The strips were to run over the shelflike floor and drape down the earth walls and extend under the new slab below. The strips of material were to be installed on 4 ft centers and fastened to the earth floor using large nails with washers.
>
> The unexcavated areas and the dirt wall (along with the network of drainage material) were to then be covered with a continuous sheet of reinforced polyethylene film. This film was to extend over the dirt wall and down underneath the slab to provide a continuous soil gas barrier. The film was to be attached to the existing block walls using caulking and treated wooden strips and masonry fasteners.

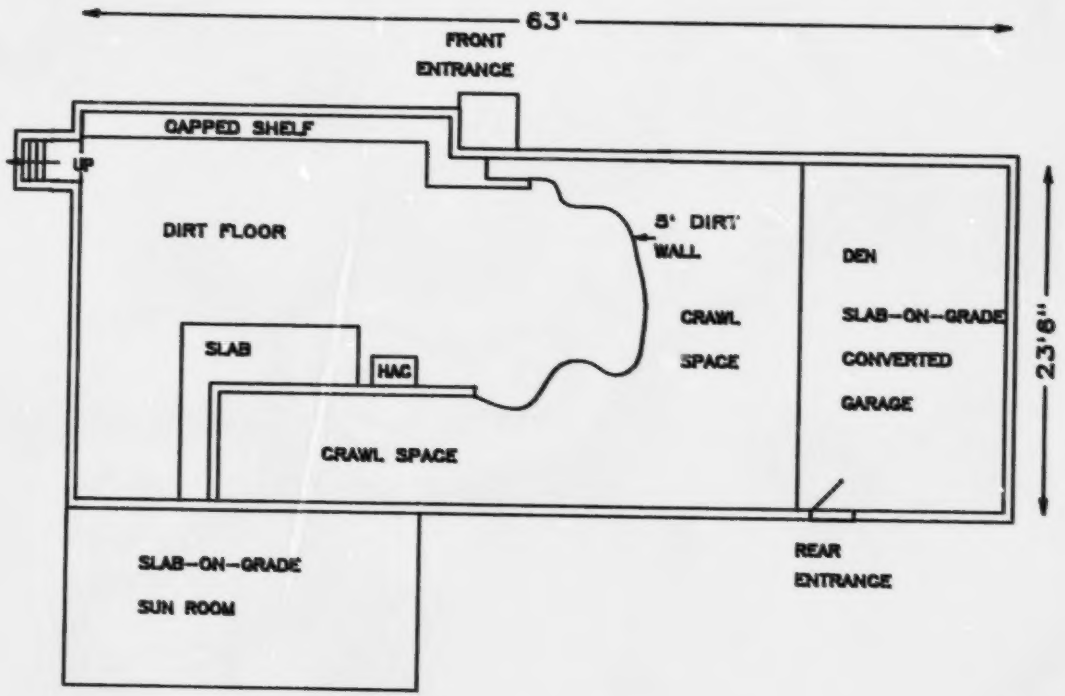

63'
FRONT
ENTRANCE
CAPPED SHELF
UP
DIRT FLOOR
5' DIRT
WALL
CRAWL
SPACE
DEN
SLAB-ON-GRADE
CONVERTED
GARAGE
23'6"
SLAB
HAC
CRAWL SPACE
SLAB-ON-GRADE
SUN ROOM
REAR
ENTRANCE

Figure 17. House DW58 basement/crawl space layout.

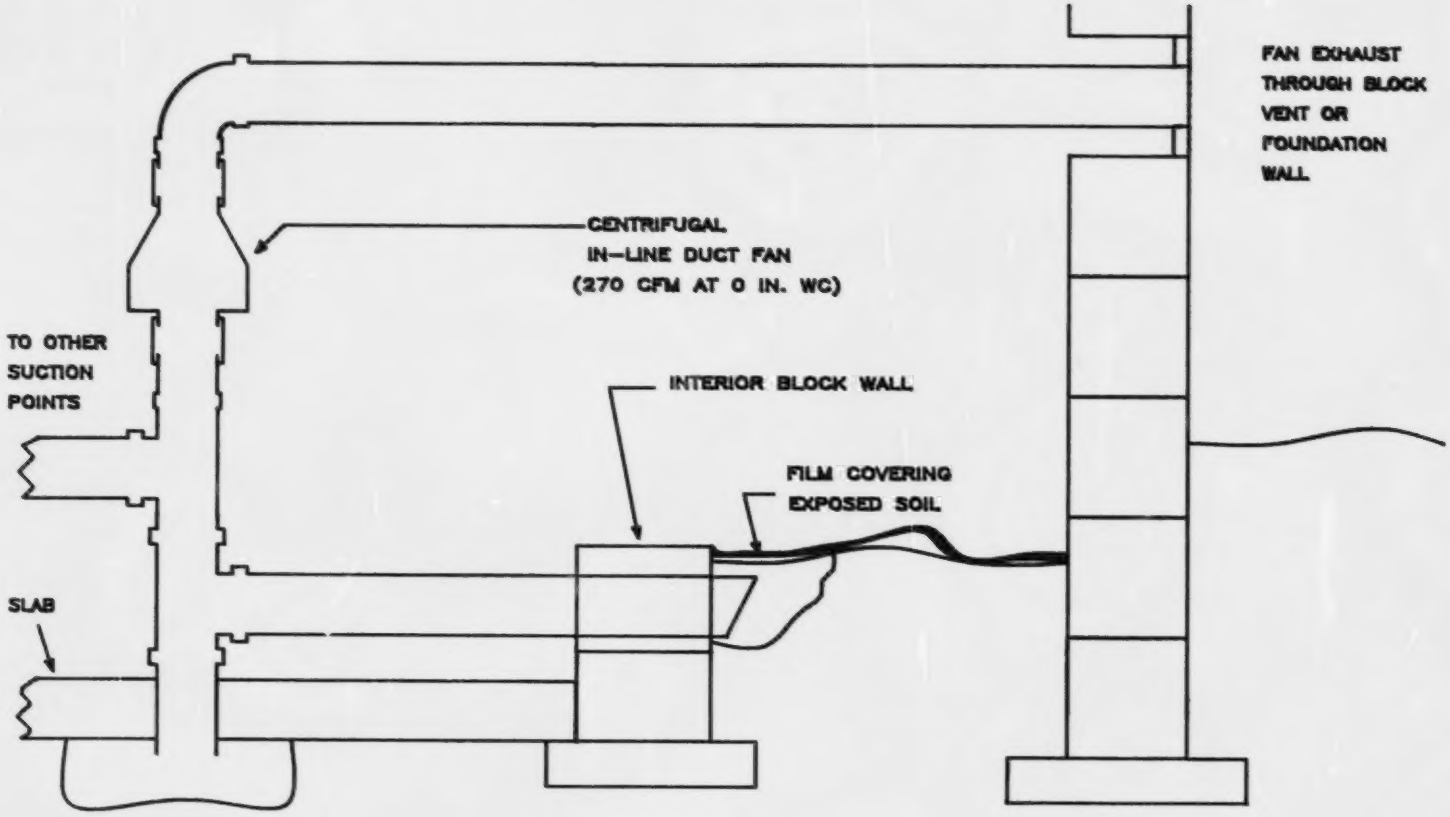

FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL
CENTRIFUGAL
IN-LINE DUCT FAN
(270 CFM AT 0 IN. WC)
TO OTHER
SUCTION
POINTS
INTERIOR BLOCK WALL
FILM COVERING
EXPOSED SOIL
SLAB

Figure 18. Sub-slab plus sub-poly depressurization system.

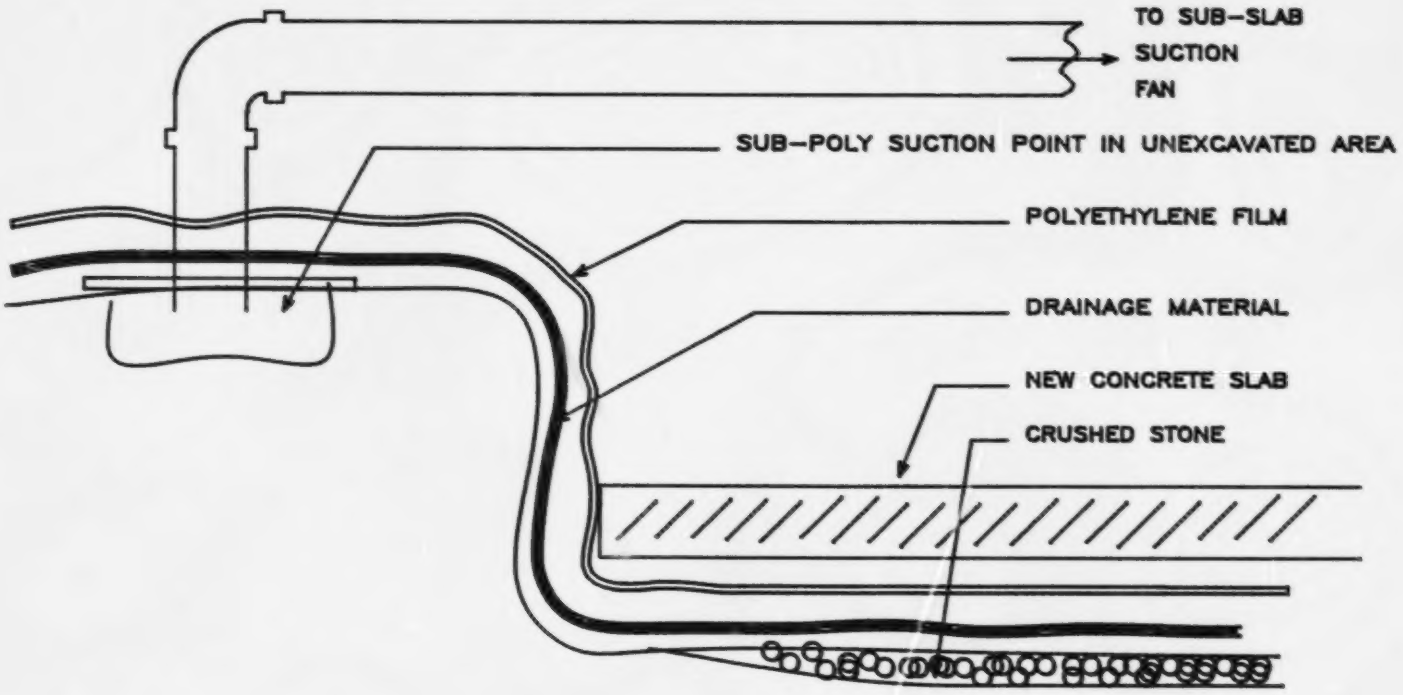

TO SUB–SLAB
SUCTION
FAN
SUB–POLY SUCTION POINT IN UNEXCAVATED AREA
POLYETHYLENE FILM
DRAINAGE MATERIAL
NEW CONCRETE SLAB
CRUSHED STONE

Figure 19. Sub–poly depressurization system detail for house DW 58.

In the event that the single sub-slab suction hole did not result in adequate reductions of the radon levels, an additional suction hole was to be added under the film covering the unexcavated areas as shown in Figure 19. This was to be a single suction hole using the same pipe and fan as used for the sub-slab suction system. At the same time, the tops of the interior concrete block retaining walls that were already in place in the building were to be sealed using expanding foam and caulking. Suction to the interior of the block walls was to be applied by tapping into the same fan system used for the sub-slab and sub-poly suction holes.

Phase 2 - Pressurization of Basement (PB)--
The second technique selected for this house was to seal the basement and pressurize and vent with the Kyle Lefkoff device described above for house DW 82. This system was selected for this house because the floor between the basement and living space was not insulated and there were few other methods that would be appropriate for this building.

Following installation of the device, as described in Figure 20, measurements of the blower flow rate and the pressure differential between basement air and outside air were to be monitored over several weeks of operation. The effects of dilution could be estimated based on these measurements.

House DW78 Mitigation Strategies

This house has a basement excavated out of an existing crawl space. There is also an existing interior concrete block wall approximately 4 feet high around the perimeter of the basement slab. The remaining area between this wall and the foundation walls of the house is open exposed soil. The area of the slab is approximately 300 ft^2 and the area of exposed soil is about 1,100 ft^2. The layout of the basement slab and adjacent crawl space areas are described in Figure 21.

Phase 1 and 2 - Sub-Slab Depressurization with Narrow/Wide Pit (SSD-N-W)--
The first technique considered for this house was depressurizing the soil using first a narrow, deep (4 in. diameter x 28 in. deep) pit, then a broad (24 in. diameter x 10 in. deep) pit, and finally a combination suction pit. Because of the poor communication observed during the diagnostic tests, two suction holes were to be installed at opposite corners of the basement slab. The details of this mitigation approach are shown in Figure 16 (minus the block wall suction tap).

Sub-slab suction was considered although tests showed poor sub-slab communication. The effects of pit size and shape upon the sub-slab communication are not well known for those cases in which there is little or no aggregate under the slab. These parameters are thought to be of little significance when communication under the slab is good to excellent. It is possible that by varying these parameters a relationship between pit size or shape and

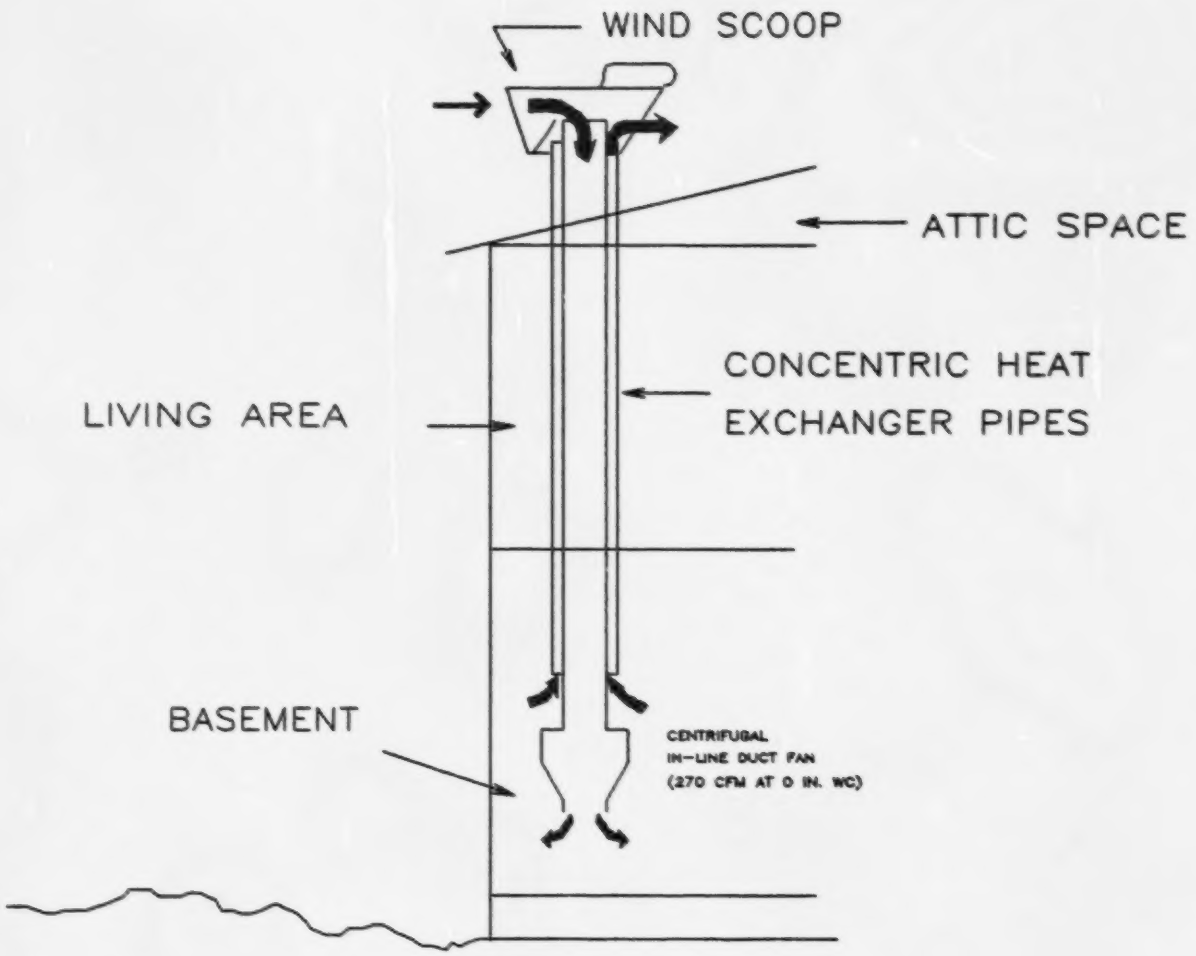

WIND SCOOP
ATTIC SPACE
CONCENTRIC HEAT EXCHANGER PIPES
LIVING AREA
BASEMENT
CENTRIFUGAL IN-LINE DUCT FAN (270 CFM AT 0 IN. WC)

Figure 20. Basement pressurization system.

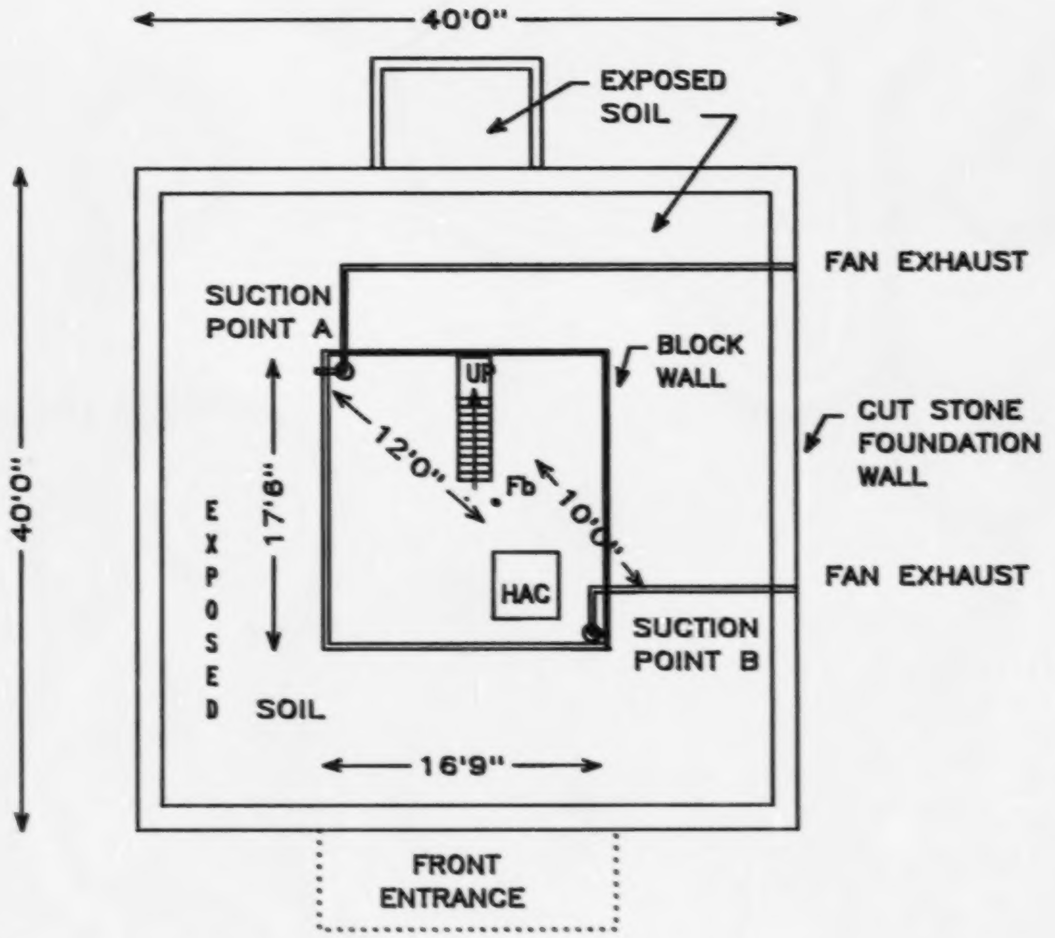

40'0"
EXPOSED SOIL
FAN EXHAUST
SUCTION POINT A
BLOCK WALL
CUT STONE FOUNDATION WALL
UP
12'0"
Fb
10'0"
40'0"
17'6"
EXPOSED
HAC
FAN EXHAUST
SUCTION POINT B
SOIL
16'9"
FRONT ENTRANCE

Figure 21. House DW78 basement/crawl space layout.

system effectiveness may be identified. Hopefully, the results of these tests would lead to a better understanding of where and when this type of mitigation system can be applied for houses with poor sub-slab communication.

In implementing this phase of the mitigation, both suction holes were to be installed at the same time, but their effectiveness was to be tested separately to determine whether one size or shape would result in a more extensive pressure field under the slab. Only one hole was to be left open at a given time. Two blowers (270 cfm at zero static pressure) with a variable speed control were to be used to provide suction power.

After installing the suction holes and fans, pressure field measurements were to be carried out under the slab. These measurements were to be carried out with first one fan on and one off, then the reverse situation, and then with both fans on. Measurements of the fan flow rates also were to be carried out.

Following the tests of pressure field extension versus pit shape, the sub-slab systems were to be operated in a combined configuration to evaluate the reductions achieved in the radon levels in the basement.

Phase 3 - Sub-Slab Plus Block Wall Depressurization (SSBWD)--

The third phase selected for this house, in the event that Phases 1 and 2 did not result in adequate reductions of the radon levels, was to use the fan systems in the first two phases to put suction on the interior block walls as shown in Figure 18. This was to be carried out by sealing the tops of the blocks forming the interior wall with expanding closed-cell foam and tapping into the interior block walls adjacent to the suction holes used in Phases 1 and 2. Following the installation the measurements of pressure fields and fan flow rates were to be repeated as well as the long term effects upon the basement radon levels.

Phase 4 - Sub-Slab Plus Sub-Poly Depressurization (SSSPD)--

If the reduction in the radon level achieved by implementing Phases 1, 2, and 3 are still not considered adequate, the exposed soil will be covered with poly film. The film will be sealed to the block tops with treated wooden strips and polyurethane caulk but will not be sealed to the stone wall at the perimeter of the building. Details of this technique are as shown in Figure 18. With the block wall depressurization system operating it is expected that adequate ventilation will be achieved under the poly film covering the crawl space areas as well.

The radon levels in the basement will continue to be monitored to assess the effectiveness of this phase of the mitigation. Also, the pressure achieved under the film will be assessed quantitatively using a micromanometer and qualitatively using smoke to visualize air flow.

Phase 5 - Pressurization of the Basement (PB)--

The final technique developed for this house was to be implemented only if the previous methods were found to be inadequate in reducing the radon levels to acceptable limits. In this phase the basement will be sealed from the upstairs living areas and pressurized/ventilated with the Kyle Lefkoff device. This technique was selected because the floor between the basement and living space was not insulated and there were few other methods that would be appropriate for this building. The pressurization and/or ventilation of the basement will be carried out as described above for house DW 58 (Phase 2), and as shown in Figure 20 above.

Following installation of the device, measurements of the blower flow rate and the pressure differential between basement air and outside air were to be monitored over several weeks of operation.

COMBINATION BASEMENT/CRAWL SPACE HOUSES

House DW12 Mitigation Strategies

This house is a combination basement/crawl space house. The crawl space area (200 ft^2) is small relative to the basement slab area (about 1200 ft^2) and should be readily dealt with by the strategies described below. The layout of the basement and crawl space is shown in Figure 22.

Phase 1 - Sub-Slab Depressurization with Progressively Larger Suction Pit Size (SSD-P)--

The first technique considered for the basement area was depressurizing the soil by putting two suction holes through the slab and then progressively making the holes in the aggregate larger. This sub-slab approach was considered even though diagnostic tests showed spotty sub-slab communication. This would give a moderate test case for the larger suction hole method under the most trying of circumstances. The progressive pits were to be dug all in one day checking only pressure field distributions so that a great deal of time would not be spent monitoring radon levels.

One suction hole was to be installed near the crawl space so that it could be easily used to depressurize the exposed soil if necessary. In implementing the SSD-P procedure the holes for the suction points were to initially just penetrate the slab as shown in Figure 23. The pits were to then be made progressively larger as the pressure differentials between basement air and sub-slab air in each quarter of the basement slab were monitored with a micromanometer. For each pit size the flow rate of the blower were to be measured to quantitate any increases in air flow under the slab.

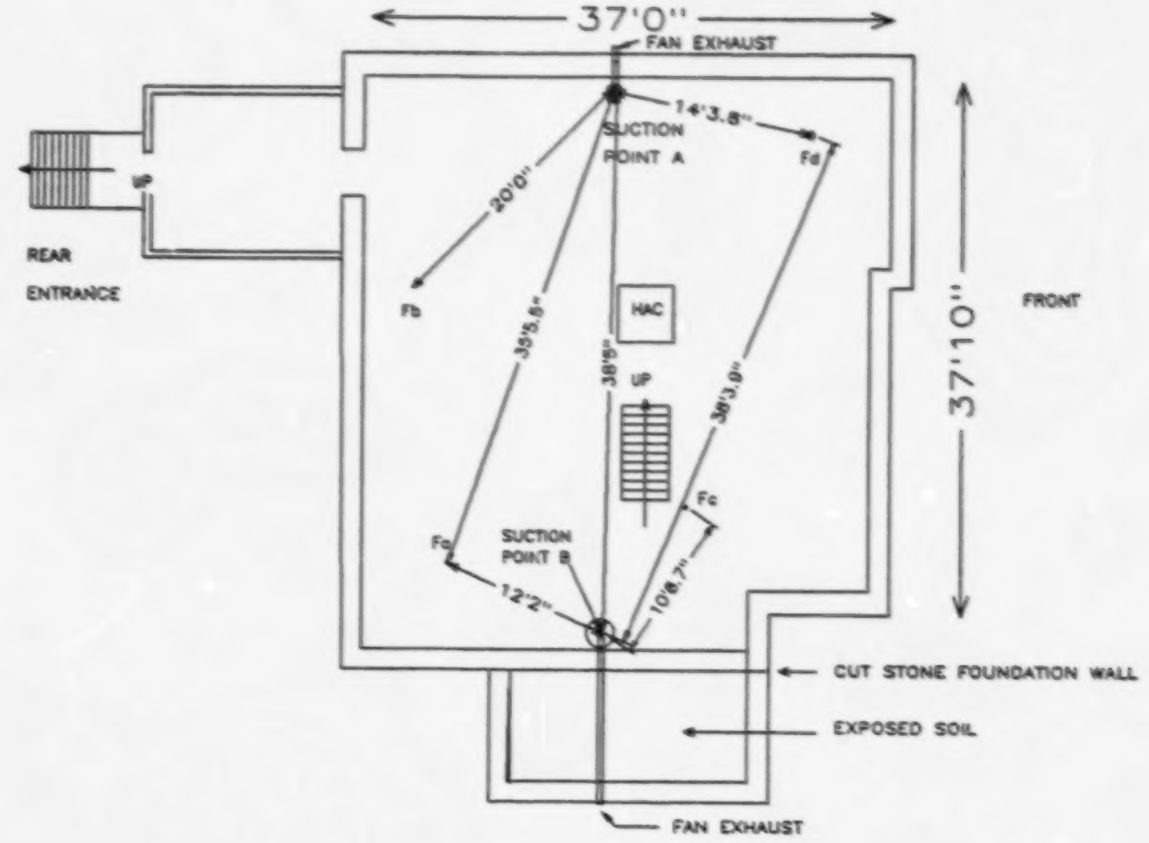

37'0"
FAN EXHAUST
14'3.8"
SUCTION
POINT A
Fd
UP
REAR
ENTRANCE
20'0"
Fb
35'5.5"
HAC
38'6"
UP
38'3.9"
37'10"
FRONT
Fc
Fa
SUCTION
POINT B
12'2"
10'8.7"
CUT STONE FOUNDATION WALL
EXPOSED SOIL
FAN EXHAUST

Figure 22. House DW12 basement floor plan.

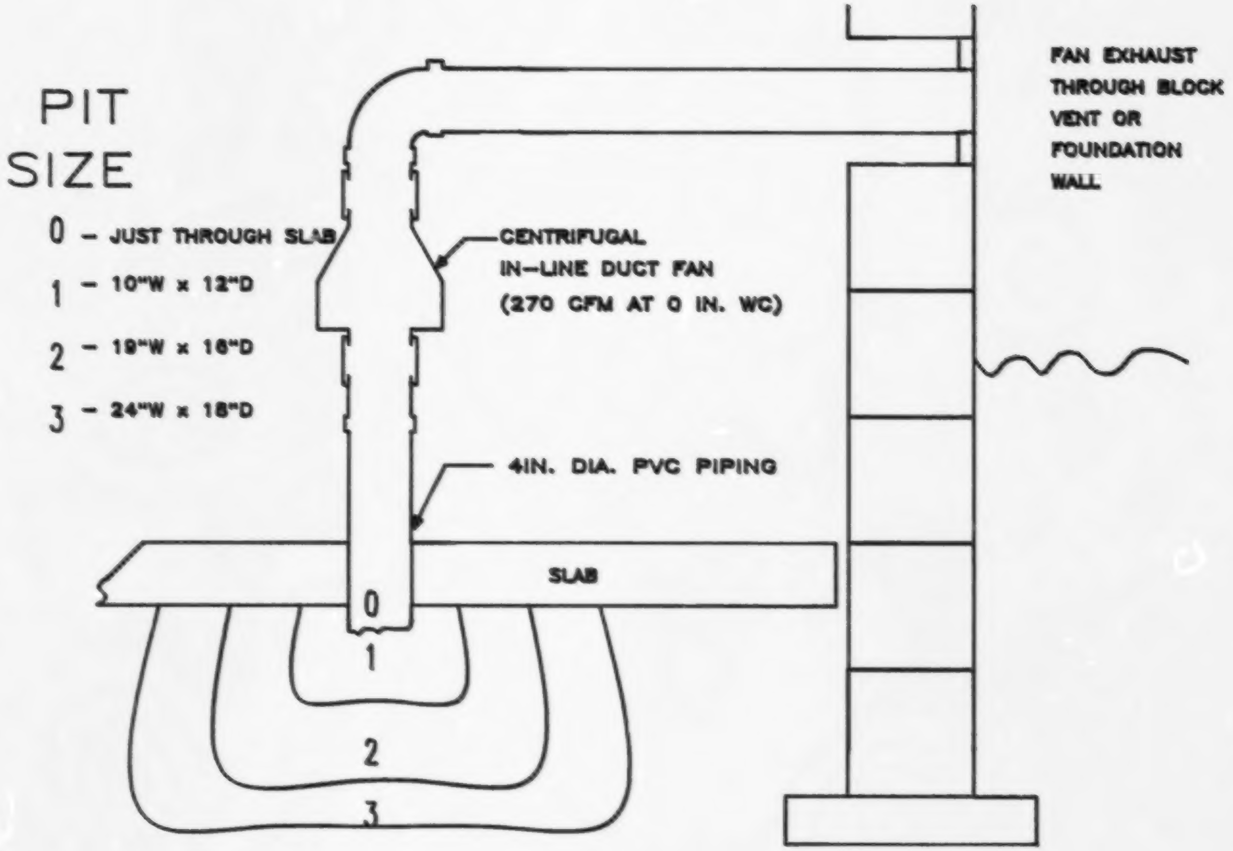

PIT
SIZE
0 – JUST THROUGH SLAB
1 – 10"W x 12"D
2 – 19"W x 16"D
3 – 24"W x 18"D
CENTRIFUGAL
IN–LINE DUCT FAN
(270 CFM AT 0 IN. WC)
4IN. DIA. PVC PIPING
SLAB
0
1
2
3
FAN EXHAUST
THROUGH BLOCK
VENT OR
FOUNDATION
WALL

Figure 23. Sub–slab depressurization with varying pit size.

Once the suction pits are expanded to their maximum size, installation of the sub-slab depressurization system was to be completed. At the same time that the SSD system was installed, the exposed soil in the basement was to be covered with 6 mil poly film. The edges of the film were not to be sealed to the cut-stone foundation walls or to the wall separating the soil from the basement slab. Sealing to such irregular surfaces was expected to be both difficult and unsuccessful.

Post-mitigation testing was to be carried out using a continuous radon monitor located in the basement. If levels were lowered sufficiently (less than 4 pCi/L), then long-term radon monitors (ATDs) were to be installed to follow the house over an extended period.

Phase 2 - Sub-Slab Plus Sub-Poly Depressurization (SSSPD)--

If tests indicate that the radon levels were still above the 4 pCi/L target, then the soil was to be ventilated using the SSD suction system located adjacent to the exposed soil area. This was to be accomplished by tapping into the suction pipe with a smaller (2 in. diameter) PVC pipe and installing a single suction point under the poly as shown in Figure 3 above for crawl space houses.

Testing was to be carried out using the continuous radon monitor located in the basement. Additional testing was to be done using a smoke source and a micromanometer to assure that the area under the poly was indeed being depressurized and no large air leaks were present.

Phase 3 - Sub-Slab Pressurization (SSP)--

In the event that implementation of Phases 1 and 2 do not lower the radon levels to acceptable limits, this third phase of mitigation was to be implemented. To apply this mitigation technique, the blowers for the SSD systems were to be reversed to force outside air under the slab in an effort to create a pressure barrier to radon entry. The exposed soil area was to either be disconnected from the system or the amount of air forced under the poly was to be throttled back to prevent ballooning of the poly.

Evaluation of this technique was to be carried out using a micromanometer to measure the pressure field generated under the slab at the same test points used during Phase 1. Radon levels in the basement were to be monitored using the continuous monitor as before.

House DW14 Mitigation Strategies

This house is a combination basement/crawl space house. The crawl space area (280 ft^2) is small relative to the basement slab area (1900 ft^2) and seemed to be a good canditate for methods similar to those used in conventional crawl space houses. The layout of the basement and crawl space is shown in Figure 24.

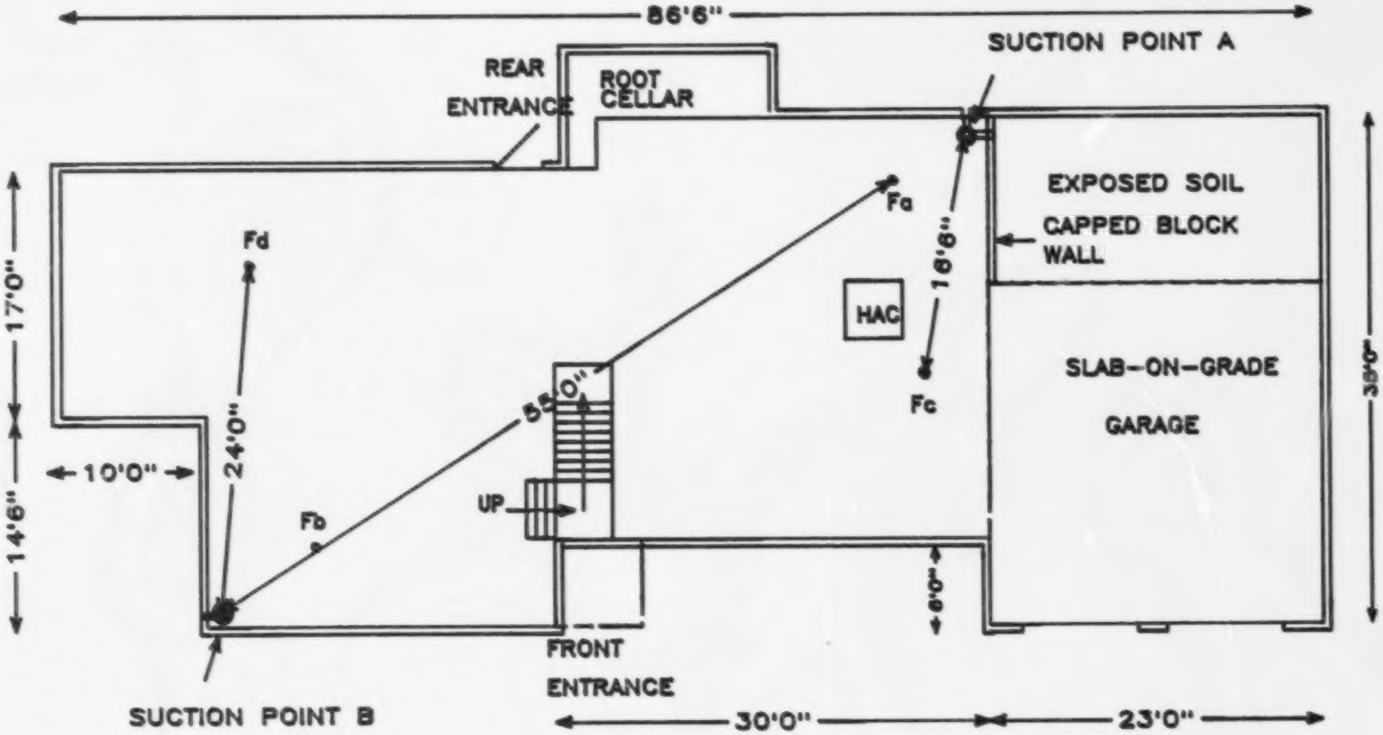

86'6"
SUCTION POINT A
REAR
ENTRANCE
ROOT
CELLAR
EXPOSED SOIL
CAPPED BLOCK
WALL
Fa
Fd
18'6"
HAC
17'0"
SLAB-ON-GRADE
GARAGE
38'0"
Fc
55'0"
24'0"
10'0"
UP
Fb
14'6"
6'0"
FRONT
ENTRANCE
SUCTION POINT B
30'0"
23'0"

Figure 24. House DW14 basement layout.

Phase 1 - Sub-Slab Depressurization with Progressively Larger Suction Pit Size (SSD-P)--

The first technique considered for the basement area was depressurizing the soil by putting two suction holes through the slab at diagonal corners and then progressively making the holes in the sub-slab material larger. This sub-slab approach was considered even though diagnostic tests showed spotty sub-slab communication. This would offer another oppertunity to evaluate the effects of hole size on the pressure field extension. The progressive pits were to be dug all in one day checking only pressure field distributions.

One suction hole was to be installed near the crawl space so that it could be easily used to depressurize the exposed soil if necessary. In implementing the SSD-P procedure the holes for the suction systems were to initially just penetrate the slab as shown in Figure 23. The pits were to then be made progressively larger as the pressure differentials between basement air and sub-slab air in each quarter of the basement slab was monitored with a micromanometer. For each pit size the flow rate of the blower was to be measured to quantitate any increases in air flow under the slab.

Once the suction pits were expanded to their maximum size, installation of the sub-slab depressurization system was to be completed. At the same time that the SSD system was installed, the exposed soil in the crawl space was to be covered with 6 mil poly film. The edges of the film were to be sealed to the concrete block foundation walls and to the top of the block wall separating the soil from the basement slab. Sealing of the film was to be carried out using urethane caulking and treated wooden strips anchored to the block with masonry fasteners. The top of the blocks in the crawl space wall were to be sealed using expanding closed-cell foam.

Post-mitigation testing was to be carried out using a continuous radon monitor located in the basement. If levels were lowered sufficiently (less than 4 pCi/L), then long-term radon monitors (ATDs) were to be installed to follow the house over an extended period.

Phase 2 - Sub-Slab Plus Block Wall Depressurization (SSBWD)--

If the radon levels in the basement are not reduced sufficiently by the two SSD systems of Phase 1, the next step to be implemented was to put a suction on the block walls of the house. This was to be carried out using the same suction systems installed in Phase 1 by tapping into the piping and into the two adjacent walls at each suction point. At the hole near the crawl space, a suction was to also be applied to the wall separating the soil and the basement. The details of this procedure are as shown in Figures 18 and 22 above.

Pressure measurements at the slab test points were to be repeated as well as points in the block walls of the basement. Radon levels were to be monitored using a continuous radon detector.

Phase 3 - Sub-Slab Plus Sub-poly Depressurization (SSSPD)--

In the event that the radon levels were still elevated following Phase 2 of the mitigation strategy, the soil in the crawl space was to be ventilated directly. This was to be accomplished by extending the suction pipe in the crawl space wall through the block and under the poly film covering the soil.

SLAB-BELOW-GRADE HOUSE

House DW41 Mitigation Strategies

This house has a finished basement with a slab of 1500 ft^2 that ranges from 4 ft below grade on the left end to at grade on the right end. Adjoining the basement slab on the right is another 600 ft^2 on grade slab for the enclosed garage. The garage slab is separated from the basement slab by a one inch thick piece of polystyrene foam at the junction. This material is also evident at the perimeter of both the basement and garage slabs. The builder apparently installed this material as a thermal break. It is not known if the same material is located below the slab. The house also has a small region of exposed soil (a crawl space) under the front porch that is in direct communication with the space under the stairs of the split foyer. The area of this exposed soil is approximately 100 ft^2. Examination of this crawl space region revealed the existence of a clay drain tile at the perimeter of the slab. The tile drains to daylight at the downhill side of the house. The basement layout of this house is shown in Figure 25.

During the intensive diagnostic evaluation it was also found that termiticide had been injected behind the baseboard throughout the basement. This finding was taken into consideration in designing the mitigation systems for this house.

Phase 1 - Sub-Slab Pressurization (SSP)--

The first technique considered for the basement area was pressurizing the soil by putting a hole through the slab and forcing ambient air through the hole. Details of this technique are similar to those shown in Figure 23 except for reversing the fan and using a single pit size (size number 3 in Figure 24). This technique has a high probability of success because of the good communication found under the slab. It was also a good candidate for this building because the basement area was finished with the exception of the region under the foyer.

The pressurization blower and slab penetration were to be located in the space under the foyer. The fresh air duct was to be run through the space under the porch and to the outside through the foundation wall of the porch. The exposed soil under the front porch was to be covered with 6 mil poly and sealed the to foundation walls with urethane caulking and treated wooden strips anchored to the wall with masonry fasteners. The crawl space was to be sealed from the area under the foyer by constructing a treated plywood bulkhead with a self-sealing door for access. The porch was to be vented with four 2 in. holes with louvered vents to allow any buildup of radon gas to disperse to the outside rather than to the foyer area.

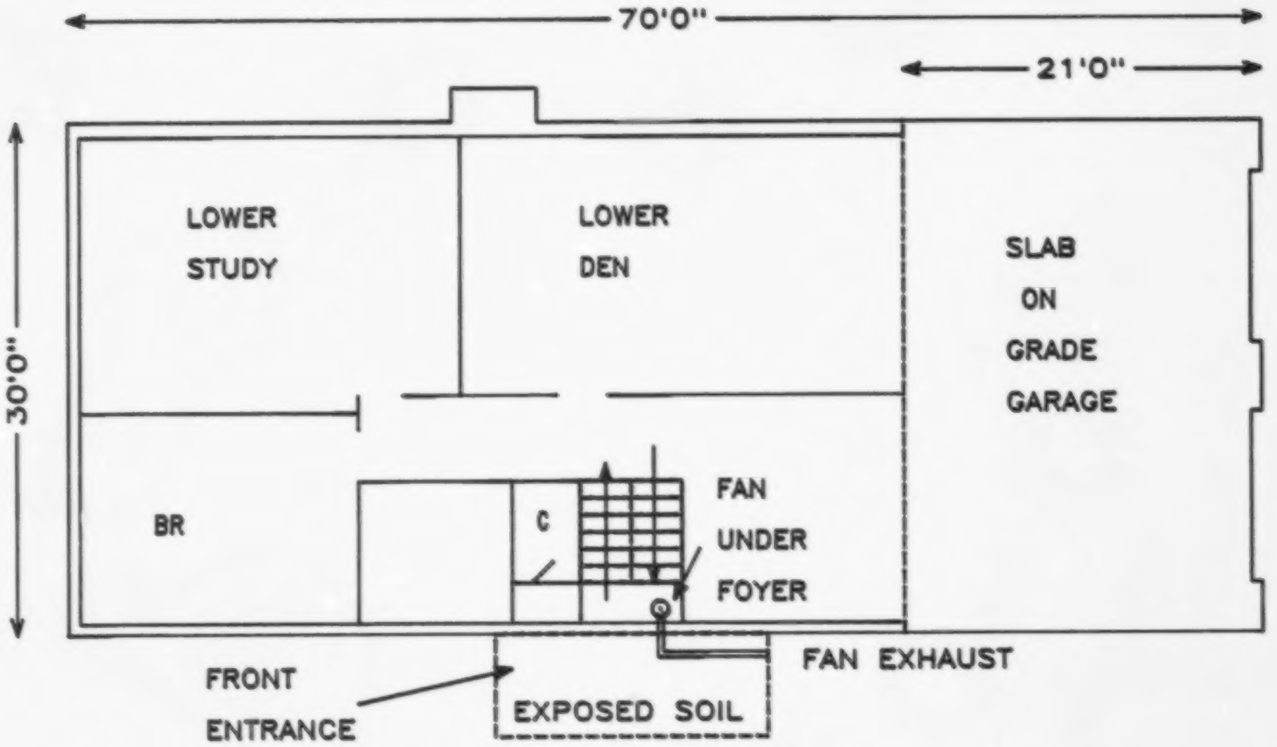

70'0"
21'0"
30'0"
LOWER STUDY
LOWER DEN
SLAB ON GRADE GARAGE
BR
C
FAN UNDER FOYER
FAN EXHAUST
FRONT ENTRANCE
EXPOSED SOIL

Figure 25. House DW41 basement plan.

System evaluation was to be accomplished by measuring the blower flow rate and the sub-slab pressures achieved at the test holes used during the diagnostic tests. The radon levels were to be measured using a continuous monitor located in the basement.

Also, in view of the termiticide placed under the slab, the pre- and post-mitigation levels of insecticide in the basement were to be measured to determine if the pressurization system caused any changes in the levels in the living areas.

Phase 2 - Sub-Slab Depressurization with Wide Pit (SSD-W)--

In the event that the Phase 1 technique did not lower the radon levels to acceptable limits, or in the event that forcing air under the slab caused problems with moisture or insecticide in the living areas, the previous system could easily be converted to a sub-slab depressurization system. This was to be accomplished simply by turning the blower around so that it exhausts air from under the slab to the outside.

This technique was to be carried out while continuously monitoring the radon levels in the basement. The sub-slab pressure measurements were to be repeated at the existing test holes. The tests for insecticide levels in the basement also were to be repeated following implementation of Phase 2.

Phase 3 - Exterior Drain Tile Depressurization (DTD)--

The final mitigation technique considered for this house was to depressurize the soil using the exterior footing drain. This was to be done in combination with sub-slab pressurization using the system installed in Phase 1. Using a positive pressure under the slab center and a negative pressure at the edges would sweep (or flush) the region under the slab of soil gas and consequently of radon gas. This technique would also prevent both radon and the termiticide from entering the basement through the polystyrene joint at the perimeter of the slab. This joint is located just behind the baseboard along all of the exterior walls of the finished basement and would be very difficult to seal.

This mitigation phase was to be implemented by installing an exterior rated blower anywhere in the exterior footer drain as described if Figure 26. The most likely locations would be under the front porch or at the end of the footer drain near the right hand side of the garage door. To prevent interference with water coming out of the footer drains, reverse flow valves were to be installed on each exposed end of the footer drains (one on each side of the garage door).

Testing of this phase of the mitigation was to follow along the same lines as outlined above for the other mitigation techniques.

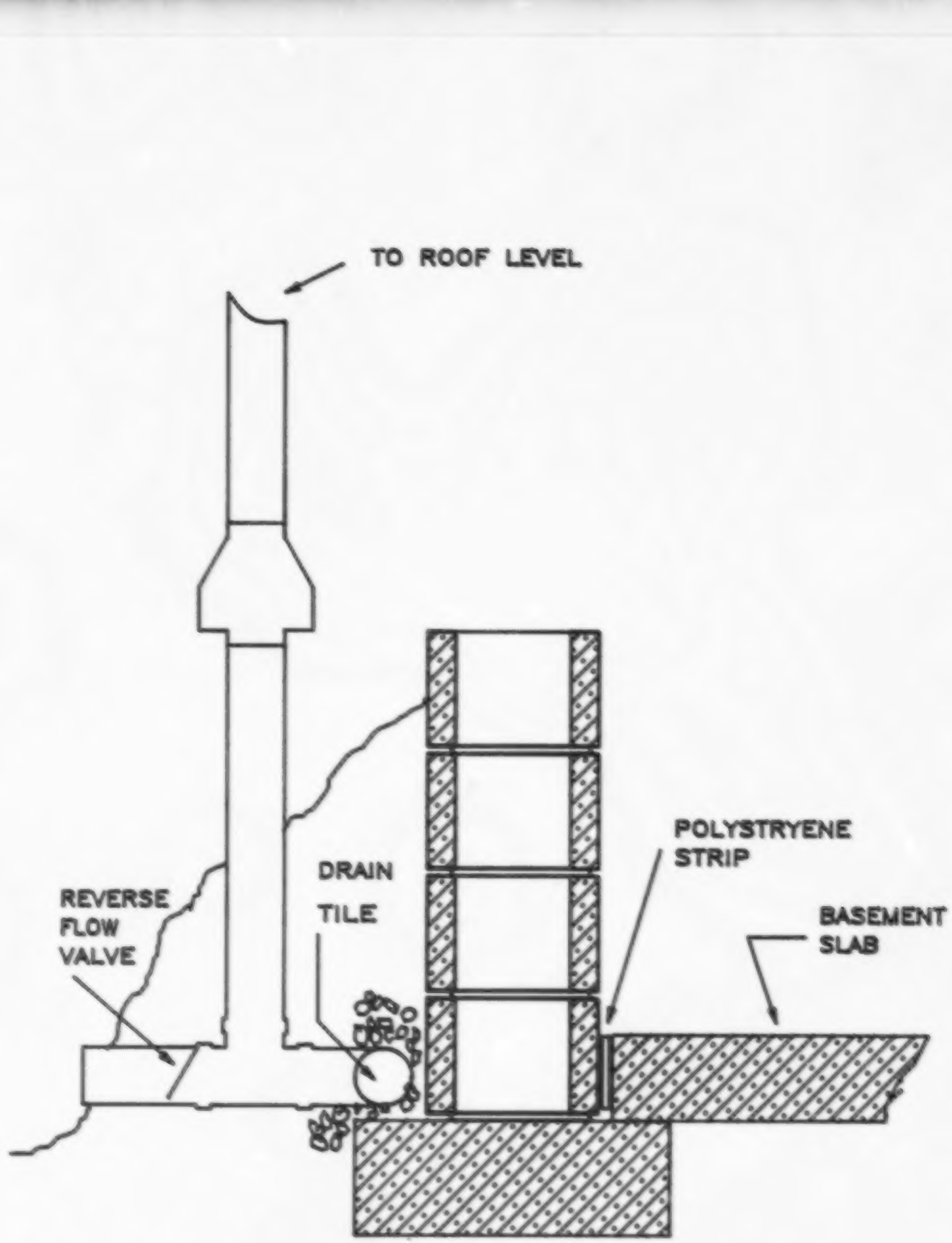

TO ROOF LEVEL
REVERSE FLOW VALVE
DRAIN TILE
POLYSTRYENE STRIP
BASEMENT SLAB

Figure 26. Drain tile depressurization system.

SECTION 6

MITIGATION OF THE NASHVILLE HOUSES

In preparation for the house mitigation work, several tasks had to be carried out in advance of the actual installations. One of these tasks was to identify and put under subcontract local contractors in the Nashville, TN, area that were capable and interested in doing radon mitigation work. To this end, interviews were set up with seven organizations who had attended one of the Radon Workshops conducted in Tennessee by Terry Brennan. These interviews were arranged by and took place in the offices of the Tennessee Department of Health and Environment, Air Pollution Control Division. Seven interested contractors were interviewed on November 17, 1987. Three were selected to work on the Nashville houses. Because of a lack of experience in estimating and doing radon mitigation work, the three contractors were allowed to mitigate two houses each at costs plus fixed fee. With the experience gained from these initial houses the contractors were then asked to give firm, fixed-price bids for each of the remaining nine houses. The houses mitigated during this initial period were DW31, DW43, DW82, DW60, DW66, and DW90. All of these are crawl space houses except DW43 which is a basement converted from a crawl space.

The remaining houses were mitigated either singularly, or at most, two houses were mitigated concurrently. The only house not mitigated during this first year (1987-88) of the project was DW58. This house is scheduled for mitigation during the early part of the second year of this project (1988-89). The schedule of house mitigations is shown in TABLE 11 where the completion date indicated is the date that the final mitigation phase was energized and found to be sufficiently effective that additional work was not necessary. This completion date does not necessarily reflect the date when this last phase was completed; rather, it indicates when the last phase was energized and tested.

Homeowner Agreements were developed and executed prior to the start of mitigation at each house. An example of the Homeowner Agreement is included in the Appendix along with a Conveyance Agreement that will be executed between SRI and the homeowner at the end of the project. This Conveyance Agreement gives legal rights to any installed equipment to the homeowners to do with as they see fit. Also, before any mitigation work other than testing was begun on the houses, a Mitigation Design Approval form, also shown in the Appendix, was executed with the homeowners. This document simply stated that SRI had explained the work to be done on the house and the homeowner gave approval for work to begin.

Another item that had to be addressed before starting the mitigation of each house was that of the reference charcoal canister (CC) measurements. The CC data obtained during the extensive diagnostic visits in October (see TABLE 5) were done during a period of seasonal weather change. The average temperature during the period ranged from 42 to 61 °F (5.6 to 16.1°C), with a minimum of 26°F (-3.3°C) and a maximum of 73°F (22.8°C). Based on prior measurements made by the homeowners, it appeared that these CC measurements were not necessarily taken during a period of maximum radon level inside the house. As a result, additional CC measurements were carried out just prior to mitigation work on each of the houses. These measurements were carried out over either 48 or 72 hour periods between November 29, 1987, and April 11, 1988. Thus, the later measurements occurred primarily during the peak heating season for the Nashville area. These later results are shown in TABLE 12. In most cases the radon levels were higher than those measured in October (TABLE 5.).

TABLE 11. MITIGATION SCHEDULE

House ID	House Type	Mitigation Started	Mitigation Completed
DW31	1	12/01/87	12/07/87
DW43	2	12/01/87	03/17/88
DW82	1	12/01/87	12/04/87
DW60	1	12/05/87	12/08/87*
DW66	1	12/04/87	12/08/87
DW90	1	12/03/87	12/09/87
DW27	1	01/25/88	02/15/88
DW41	4	01/25/88	02/02/88
DW12	3	02/08/88	02/10/88
DW14	3	02/10/88	03/04/88
DW29	1	02/22/88	03/10/88
DW78	2	02/22/88	03/15/88
DW84	1	03/21/88	03/30/88
DW03	1	04/11/88	04/12/88
DW58	2	**	

House Type: 1 - Crawl Space
2 - Basement converted from crawl space
3 - Combination basement / crawl space
4 - Slab-below-grade
* - More work scheduled during the next year
** - Mitigation scheduled during the next year

The results obtained from the alpha track detectors installed in October 1987 are shown in TABLE 13. These detectors were removed from the houses just prior to the start of mitigation for each house; consequently, the length of exposure varies from house to house. Also note that two detectors, numbers 619114 and 619115, had anomalously low values for a crawl space location. Also, two other detectors shown in TABLE 13 had to be voided (numbers 619083 and 619112). After discussions with the supplier (Tech/Ops Landauer, Inc., Glenwood, IL) it was concluded that perhaps the plastic detector strips were positioned incorrectly in the detector case. Consequently, the values shown in TABLE 13 for these detectors are considered to be invalid. Additional discussion relative to ATD errors is covered in SECTION 8.

TABLE 12. NASHVILLE PRE-MITIGATION COLLOCATED CHARCOAL RESULTS (NOV'87 TO APR'88)

House ID #	Start Date	Stop Date	Crawl Space		Basement		1st Habitable Level	
DW 03	4/08/88	4/11/88	21.6	22.1	NA	NA	7.0	7.1
DW 12	2/05/88	2/08/88	NA	NA	10.3	11.8	7.7	7.8
DW 14	2/08/88	2/10/88	NA	NA	89.9	86.7	47.1	48.1
DW 27	1/22/88	1/25/88	45.7	46.4	NA	NA	32.8	33.0
DW 29	2/19/88	2/22/88	27.1	27.2	NA	NA	15.9	16.2
DW 31	11/29/87	12/1/87	29.4	30.3	NA	NA	26.3	25.7
DW 41	1/22/88	1/25/88	NA	NA	19.2	19.3	13.3	13.4
DW 43	11/29/88	12/1/87	NA	NA	58.6	59.7	23.2	22.9
DW 58	3/29/88	3/31/88	NA	NA	56.2	57.3	20.4	27.4
DW 60	12/01/87	12/3/87	55.2	55.0	NA	NA	27.9	27.8
DW 66	12/01/87	12/3/87	26.1	25.9	NA	NA	12.3	11.9
DW 78	2/19/88	2/22/88	NA	NA	41.2	41.5	19.6	19.9
DW 82	11/29/87	12/1/87	29.5	30.0	NA	NA	14.7	15.1
DW 84	3/28/88	3/30/88	9.4	9.7	NA	NA	1.5	2.3
DW 90	12/01/87	12/3/87	29.6	29.7	NA	NA	15.8	15.8

NA - Not Applicable

In the following paragraphs the mitigation efforts at each house will be discussed separately. The discussions are grouped by house type and not necessarily in the order they were mitigated. For the chronology see TABLE 11.

TABLE 13. PRE-MITIGATION COLLOCATED ALPHA TRACK DETECTOR RESULTS FOR NASHVILLE HOUSES (1987-88)

Detector Number	House ID and Location	Install Date	Remove Date	Days Exposure	Radon Level (pCi/L)	Comments
619118	DW03-C	10/26/87	04/11/88	168	16.7	
619122	DW03-C	10/26/87	04/11/88	168	16.8	
619120	DW03-L	10/26/87	04/11/88	168	8.1	
619121	DW03-L	10/26/87	04/11/88	168	7.7	
619162	DW12-B	10/22/87	02/08/88	109	10.0	
619163	DW12-B	10/22/87	02/08/88	109	12.0	
619164	DW12-L	10/22/87	02/08/88	109	9.6	
619180	DW12-L	10/22/87	02/08/88	109	10.3	
619190	DW14-B	10/22/87	02/10/88	111	36.1	
619191	DW14-B	10/22/87	02/10/88	111	35.4	
619143	DW14-L	10/22/87	02/10/88	111	24.7	
619188	DW14-L	10/22/87	02/10/88	111	20.3	
619137	DW27-C	10/24/87	01/25/88	93	35.4	
619138	DW27-C	10/24/87	01/25/88	93	32.6	
619139	DW27-L	10/24/87	01/25/88	93	23.5	
619140	DW27-L	10/24/87	01/25/88	93	23.7	
619193	DW29-C	10/23/87	02/22/88	122	16.6	
619194	DW29-C	10/23/87	02/22/88	122	20.4	
619195	DW29-L	10/23/87	02/22/88	122	12.0	
619196	DW29-L	10/23/87	02/22/88	122	11.1	
619114	DW31-C	10/23/87	12/02/87	40	2.6	1
619115	DW31-C	10/23/87	12/02/87	40	1.8	1
619165	DW31-L	10/23/87	12/02/87	40	19.1	
619125	DW31-L	10/23/87	12/02/87	40	21.3	
619178	DW41-B	10/22/87	01/25/88	95	15.5	
619177	DW41-B	10/22/87	01/25/88	95	15.8	
619189	DW41-L	10/22/87	01/25/88	95	9.8	
619179	DW41-L	10/22/87	01/25/88	95	11.8	
619185	DW43-B	10/21/87	12/02/87	42	36.3	
619186	DW43-B	10/21/87	12/02/87	42	33.1	
619183	DW43-L	10/21/87	12/02/87	42	16.9	
619184	DW43-L	10/21/87	12/02/87	42	17.0	

(continued)

TABLE 13. (continued)

Detector Number	Location and House ID	Install Date	Remove Date	Days Exposure	Radon Level (pCi/L)	Comments
619084	DW60-C	10/26/87	12/04/87	39	2.0	
619086	DW60-C	10/26/87	12/04/87	39	2.5	
619112	DW60-L	10/26/87	12/04/87	39	0.4	1
619160	DW60-L	10/26/87	12/04/87	39	15.6	
619156	DW66-C	10/27/87	12/03/87	37	22.5	
619158	DW66-C	10/27/87	12/03/87	37	23.0	
619159	DW66-L	10/27/87	12/03/87	37	13.5	
619197	DW66-L	10/27/87	12/03/87	37	9.9	
619170	DW78-B	10/21/87	02/22/88	124	24.3	
619171	DW78-B	10/21/87	02/22/88	124	27.8	
619172	DW78-L	10/21/87	02/22/88	124	18.7	
619173	DW78-L	10/21/87	02/22/88	124	12.9	
619127	DW82-C	10/26/87	12/02/87	37	18.4	
619135	DW82-C	10/26/87	12/02/87	37	21.2	
619192	DW82-L	10/26/87	12/02/87	37	9.1	
619136	DW82-L	10/26/87	12/02/87	37	11.7	
619129	DW84-C	10/23/87	03/25/88	154	10.9	
619130	DW84-C	10/23/87	03/25/88	154	9.6	
619131	DW84-L	10/23/87	03/25/88	154	5.8	
619132	DW84-L	10/23/87	03/25/88	154	4.4	
619141	DW90-C	10/24/87	12/03/87	40	25.5	
619161	DW90-C	10/24/87	12/03/87	40	23.9	
619083	DW90-L	10/24/87	12/03/87	40	1.3	1
619085	DW90-L	10/24/87	12/03/87	40	12.3	

Note: Location codes are C - Crawl Space, B - Basement, and L - First habitable level of the house above crawl space or basement.
Comments : 1 - These detectors voided see text for details

CRAWL SPACE HOUSES

House DW03

This crawl space house was mitigated during the week of 4/11/88. Radon levels in the living room were monitored with a continuous radon monitor (CRM) during the pre-mitigation period, the time the mitigation systems were installed, and during the post-mitigation evaluation period. The device used was an AB5 radon detector with a PRD1 passive cell attached (AB5 with PRD1, Pylon Electronic Development Co., Inc., Ottawa, Ontario)).

Pre-mitigation Evaluation--

Pre-mitigation charcoal canister measurements (shown in TABLE 12) were carried out over the period 4/8/88 to 4/11/88 and gave radon levels of 21.8 pCi/L in the crawl space and 7.1 pCi/L in the living room of the house. The latter value agrees well with that obtained with the (CRM) over the same period: 6.82/1.94/11.68/2.75 pCi/L (these numbers represent the average/minimum/maximum/standard deviation of the hourly readings from the CRM). The coefficient of variation (CV) of the radon levels during this period was 0.4 (standard deviation/average value). The CRM readings for this house are shown in Figure 27, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

The mitigation installations carried out in this house were as follows Phase 1 (IVCS) sealing and caulking all openings between crawl and upstairs as well as possible and passively venting the crawl space; Phase 2 (SPD) covering all exposed soil with 6 mil polyethylene sheeting and attaching a Turbo T^2 fan (model T^2 Turbo 6, R.B. Kanalflakt, Inc., Sarasota, FL) to depressurize under the sheeting. The edges of the sheets were overlapped by a minimum of 12 inches. The sheeting was not attached to the foundation walls nor to the support piers.

Phase 1 (IVCS) Evaluation--

During the period 4/12/88 to 4/19/88 the results of sealing the openings between house and crawl space and passively ventilating the crawl space were evaluated. All but two block vents were closed and sealed. The radon levels in the living room as measured with the CRM during this period were: 5.56/0.59/13.74/3.26 pCi/L (ave/min/max/std.dev). The CV of the radon levels during this period was 0.6. This represents a reduction of about 18% from the pre-mitigation level of 6.82 pCi/L. Large diurnal variations in the radon level were observed during the passive ventilation tests as shown by the much larger coefficient of variation (50% larger). The reasons for this are not understood at this time but could be due in part to the build-up of radon gas in the crawl space during periods of quiescent air flow outside the house.

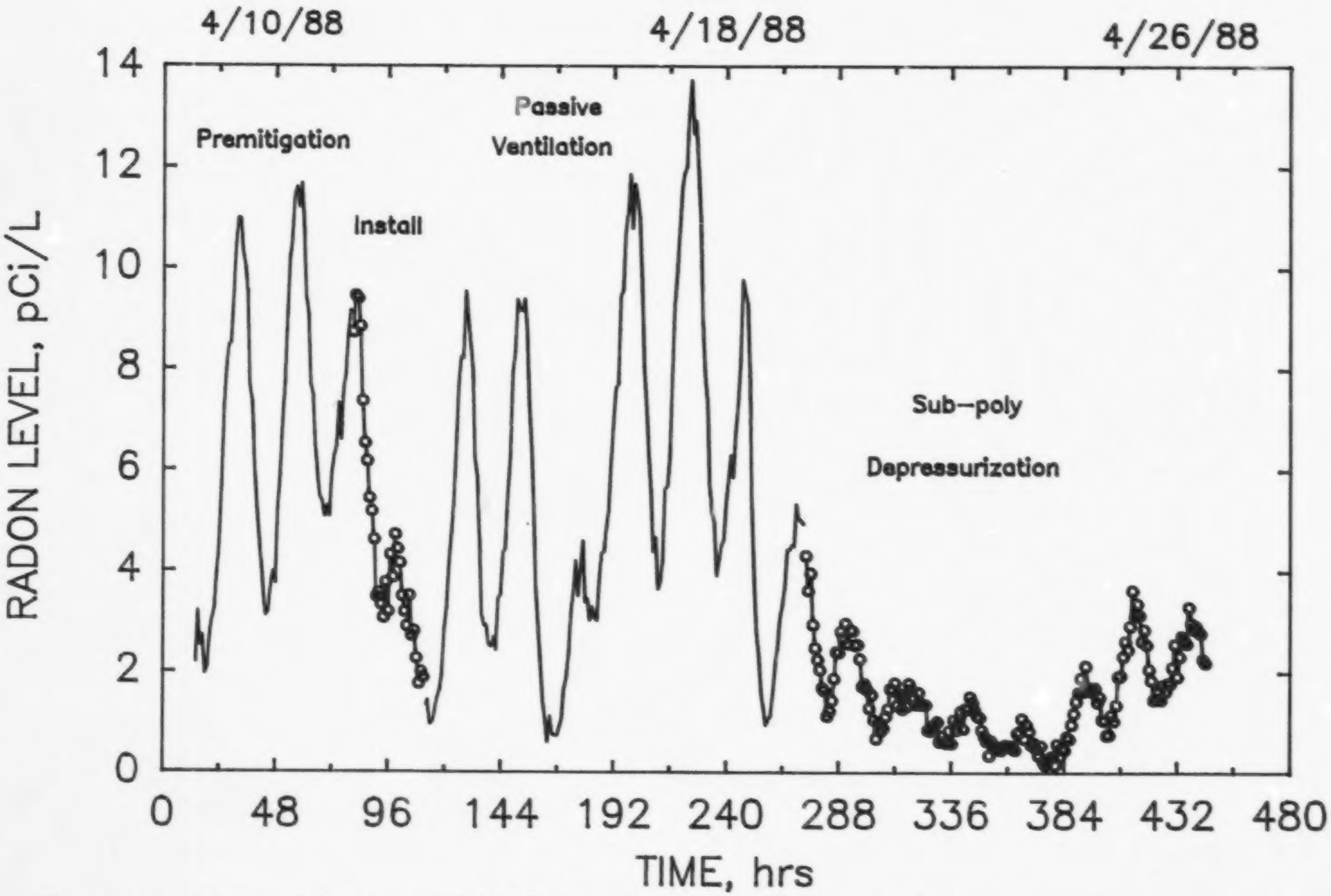


Figure 27. House DW03 continuous radon levels measured in living room.

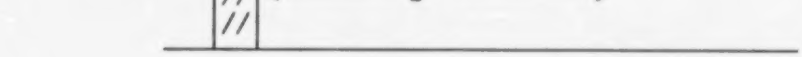
Phase 2 (SPD) Evaluation--

The sub-poly depressurization fan was energized on 4/19/88, and the radon levels in the living room were monitored continuously over the period 4/19/88 to 4/26/88. The radon levels measured over this period were: 1.48/0.16/3.62/0.81 pCi/L (ave/min/max/std.dev). These values represent a reduction of about 78% from the pre-mitigation levels. The coefficient of variation during this period was approximately 0.5 which is smaller than that observed during the passive ventilation phase but still larger than that observed during the pre-mitigation period.

Post-mitigation charcoal canister measurements were carried out (in the living room only) over the period 2/24/88 to 2/26/88. These measurements indicated the level to be 2.6 pCi/L or approximately 88% less than that during the pre-mitigation period. To compare the charcoal canister results to those obtained with the continuous monitor, the continuous monitor readings over the same 48 hour period were analyzed. The results obtained gave excellent agreement with the CC data (2.14/0.75/3.62/0.72 pCi/L) (ave/min/max/std.dev)

Pressure measurements were made under the poly sheeting to determine the extent of the depressurization field established. The location of these test points are shown in Figure 2. The results of these measurements, along with the values measured at the other houses having sub-poly depressurization systems installed, will be discussed in Section 7.

Grab radon samples were taken at the fan exhaust outlet to map the radon concentrations expelled by the mitigation system. The concentrations measured at various locations are as shown below. The radon exhausted from the SPD system are low enough at distances of 2 ft or more that the exhaust is not considered a safety hazard.



No additional work on this house is anticipated until the homeowner goes ahead with plans to have a central forced air heating and air conditioning system installed. At that time we hope to be able to install continuous monitors in both the living area and in the crawl space to measure the effects, if any, resulting from changes in the house environment or damage to the polyethylene sheeting. Long-term alpha track detectors were installed on 5/10/88 and will be replaced quarterly for the next 2 years.

House DW27

DW27, a combination basement/crawl space house, received the Phase 1 (SPD) mitigation during the week of 1/25/88. This was the only mitigation phase installed in this house. However, several modifications were made to the sub-poly depressurization (SPD) system over a period of several weeks. These are as described below.

Pre-mitigation Evaluation--

Pre-mitigation continuous radon measurements were carried out in the living room over the period 1/22/88 to 1/27/88 using a Pylon AB-5 equipped with a PRD-1 passive radon cell. The results of these measurements were 30.5/7.3/39.5/6.7 pCi/L (ave/min/max/std.dev). The average value of 30.5 pCi/L agrees well with the value 32.9 pCi/L obtained with CC measurements made over the period 1/22/88 to 1/25/88. The CRM readings for this house are shown in Figure 28, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

The Phase 1 mitigation system designed for this house was installed during the week of 1/25/88. This included covering the crawl space with polyethylene with 12 inch wide strips of drainage material (Enkadrain, type 9010, BASF Corporation, Fibers Division, Enka, NC) strategically located underneath the plastic to improve air flow. A single sub-poly suction point was installed near the far end of the crawl using an inline fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) exhausting through a block vent in the foundation wall. A strip of EPDM rubber matting was installed over the poly to provide access to the HAC system located in the crawl space. The locations of the suction point and the EPDM walkway are shown in Figure 4.

Phase 1 (SPD) Evaluation--

The sub-poly fan was energized at 1800 hrs on 1/27/88. Testing with the Pylon AB-5 continuous radon monitor located in the living room (results of which are shown in Figure 28) over the period 1/27/88 to 2/03/88 showed that the average radon levels in the living room were 8.2/2.8/15.4/2.7 pCi/L (ave/min/max/std.dev). The continuous monitor was interrupted over the period 2/4/88 to 2/5/88 due to the homeowner turning off a wall switch that controlled the wall electrical outlet that the AB-5 battery charger was connected to. The situation was corrected on 2/5/88, and the continuous monitoring was continued until 2/11/88. Over this latter period (2/5/88 to 2/11/88) the radon levels in the living room were 12.1/8.7/15.9/1.5 pCi/L (ave/min/max/std.dev).

Because these values were above the target figure of 4 pCi/L, it was decided to modify the SPD system in an effort to improve the efficiency of the system while gaining more insight into the operation of the SPD technique.

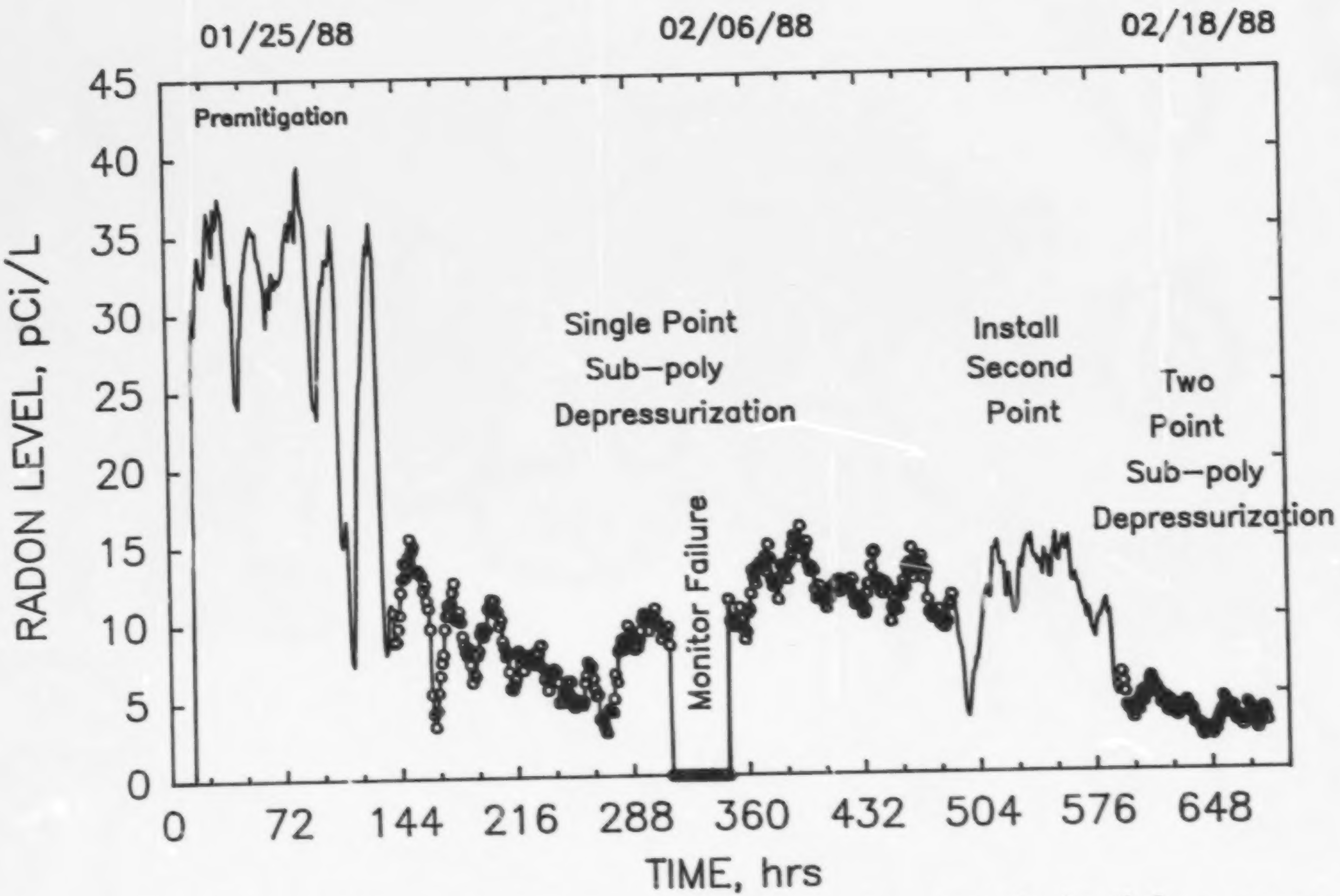


Figure 28. House DW27 continuous radon levels in living room.

This included adding a second suction point under the plastic sheeting using the same fan, as well as sealing the plastic at the concrete walls, to the adjoining slab, the piers, and at the sheet overlap joints. The second suction point was located near the entrance end of the crawl space (see Figure 4).

This modification was completed on 2/15/88. The radon levels in the living room over the period 2/15/88 to 2/19/88 were 3.8/2.2/6.3/0.9 pCi/L (ave/min/max/std.dev). At this time it was thought that the levels in the living areas were sufficiently close to the target value that the house could be considered fixed. However, subsequent charcoal canister measurements taken during the period 2/23-25/88 gave an average value of 5.2 pCi/L in the living room and 9.2 pCi/L in the basement/crawl space. Duplicate collocated alpha track detectors were installed at this time. With the levels so close to the target value, it was decided to reevaluate the house after the ATD monitors have been exposed for an extended period of time. Long-term alpha track detectors were installed on 2/23/88 and will be replaced quarterly for the next 2 years.

House DW29

DW29, a crawl space house, had the first two phases of mitigation installed during the week of 2/22/88.

Pre-mitigation Evaluation--

Prior to mitigation of the house, a continuous monitor was installed on 2/19/88 to obtain pre-mitigation radon levels. The resultant levels in the den over the period 2/19/88 to 2/22/88 were 16.3/12.9/18.9/1.4 pCi/L (ave/min/max/std.dev). This agrees well with the value obtained with duplicate CC measurements over the same period of 16.1 pCi/L (TABLE 12). The CRM readings for this house are shown in Figure 29, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

The Phase 1 (ICS) mitigation for this house was to seal as completely as possible all openings from the crawl space to the living area of the house. The intent of this was to determine the effectiveness of sealing entry points to reduce or preclude the entry of radon into the living areas. In applying this phase it was found that when the builder installed the central forced air heating and air conditioning system, he used the floor joists to form a box plenum for the cold air return (a common practice). This was accomplished by installing two pieces of joist stock between the existing joists and approximately 24 inches apart. This was then covered from below with sheet metal to form a plenum. The floor above was cut away to form an air passage in the den wall where a return air filter and register were located. From below, the plenum was connected to the conditioning system with insulated 18 inch diameter ducting. Numerous openings were discovered in this insert

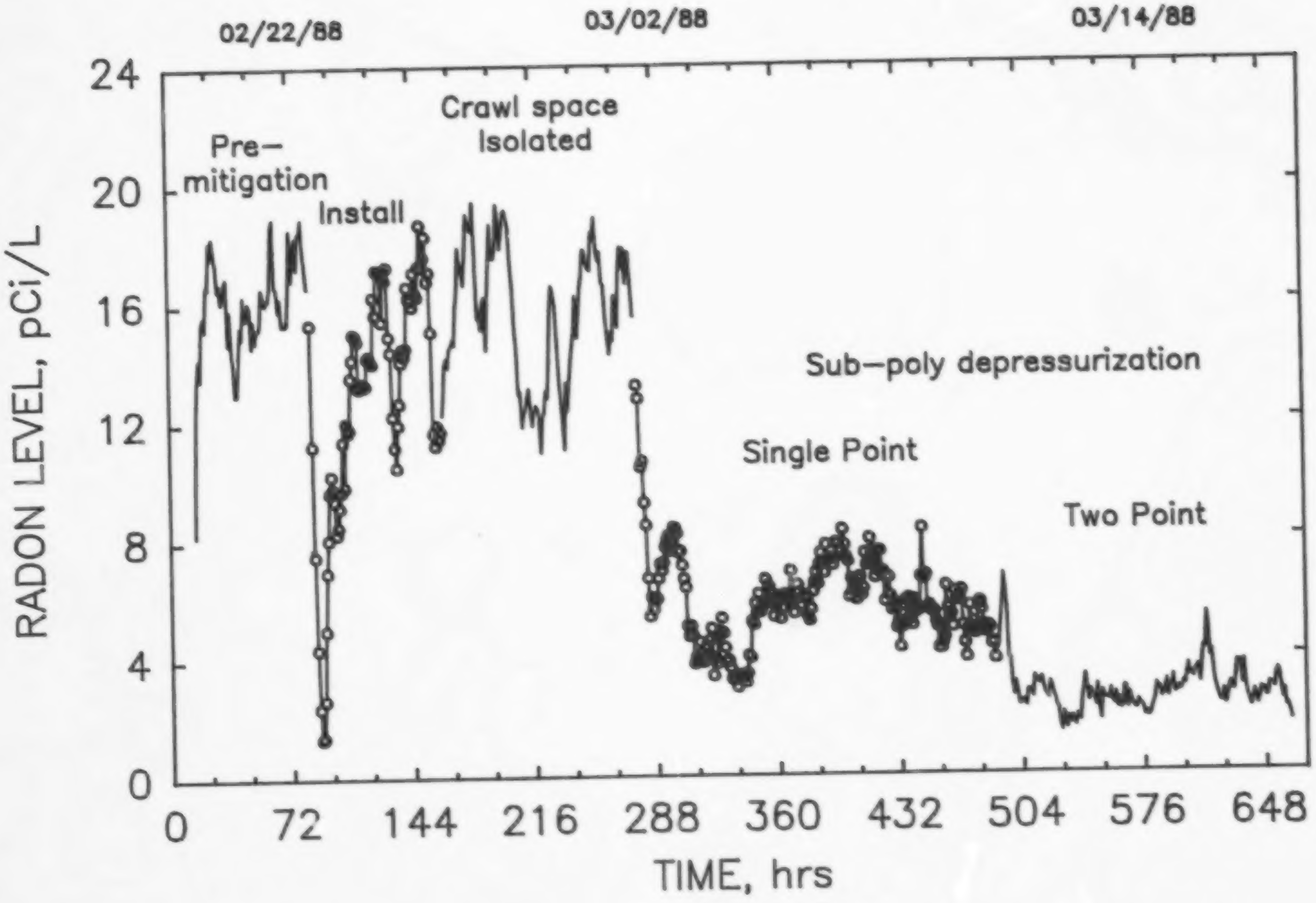


Figure 29. House DW29 continuous radon levels in den.

return plenum ranging in size from 1/16 inch and less to one large enough to put a hand through. The system was freely drawing crawl space air into the cold air return and then distributing this throughout the house. These leaks were closed and sealed as well as possible. Also, the clothes dryer vent which was found during the diagnostic tests to exhaust into the crawl space, was rerouted to the outside of the house.

At the same time that the sealing was done, the Phase 2 (SPD) mitigation system was also installed. The second phase was to cover all exposed soil with 6 mil polyethylene sheeting and install a depressurization fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) to draw the radon and soil gas from under the sheeting. The exhaust from the fan was expelled through a block vent at the front of the house.

Phase 1 (ICS) Evaluation--

Sealing of the openings from the crawl space to the living areas and installation of the polyethylene sheeting and one sub-poly suction point was carried out over the period 2/22/88 to 2/25/88. Following installation of these initial mitigation phases, the suction fan was left unenergized over the period 2/25/88 through 3/1/88 to determine if the attempts to seal the openings would reduce the radon levels in the living area. Because the floor between the living areas and the crawl space was not insulated and because there were HAC ducts in the crawl space, all block vents were left closed during the test. The values obtained with the continuous radon monitor over the period 2/25/88 to 3/1/88 were 15.7/10.9/19.5/2.2 pCi/L (ave/min/max/std.dev). From this data the actual reduction in the radon levels achieved by sealing alone was only about 3 percent. This value of reduction is clearly within the experimental error of measurement.

Phase 2 (SPD) Evaluation--

The sub-poly fan was energized at 1100 hrs on 3/1/88 and the continuous monitor allowed to follow the radon levels in the den of the house. The levels over the period 3/1/88 to 3/10/88 were 5.8/3.0/9.2/1.3 (pCi/L) (ave/min/max/std.dev). Collocated CC measurements carried out over the period 3/4/88 to 3/7/88 gave values of 5.6 and 5.7 pCi/L in the crawl space and 7.0 and 7.0 pCi/L in the den. These values were above the target level of 4 pCi/L, so a second sub-poly suction point was installed using the same fan on 3/10/88.

Continuous radon measurements with both suction points active resulted in levels over the period 3/10/88 to 3/17/88 of 2.7/1.4/5.4/0.6 pCi/L (ave/min/max/std.dev). These levels were confirmed with post-mitigation charcoal canister measurements carried out over the period 3/15/88 to 3/17/88 which gave results of 2.7 and 2.8 pCi/L in the crawl space and 2.9 and 3.0 pCi/L in the den. No further mitigation work is contemplated for this house. Long-term alpha track detectors were installed on 3/22/88 and will be replaced quarterly.

House DW31

This house is a crawl space house with a slab-on-grade garage converted into a living room. The house is heated in the winter with resistance strip heaters and cooled in the summer with a window mounted air conditioner. There are no ducts in the crawl space, and the floor over the crawl is not insulated. The Phase 1 (SSoD) mitigation designed for this house is a four pit soil depressurization system. There is no vapor barrier covering the soil, and the soil itself appears to be fairly porous as determined during the intensive diagnostic tests carried out in October 1987. This house was one of the first houses to be mitigated during December 1987.

Pre-mitigation Evaluation--

Pre-mitigation monitoring with the continuous radon monitor over the period 11/29/87 to 12/1/87 gave levels in the living room of 24.6/21.5/30.8/2.5 pCi/L (ave/min/max/std.dev). The average value of 24.6 pCi/L agrees well with collocated CC measurements (see TABLE 11) taken over the same period. These CC results were 29.4 and 30.3 pCi/L in the crawl space and 25.7 and 26.3 pCi/L in the living room. The CRM readings for this house are shown in Figure 30, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

In installing the soil depressurization system, four pits approximately 24 inches in diameter and 18 inches deep were excavated in the crawl space. One pit was located in each quarter of the area as shown in Figure 37. The pits were then covered with treated plywood covers and covered with the excavated soil as described in Figure 8 above. The pits were connected with 4 inch diameter PVC pipe to a single inline fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) exhausting the soil gas through a block vent in the foundation wall.

Phase 1 (SSoD) Evaluation--

Initially only two diagonal pits (pits A and B shown in Figure 7) were connected. The radon levels in the living room were monitored with these two pits active over the period 12/4/87 to 12/7/87. These levels were 9.5/4.1/15.0/2.9 pCi/L (ave/min/max/std.dev). At 0900 hrs on 12/7/87 the remaining two pits were connected into the system. The levels monitored over the period 12/7/87 to 12/8/87 were 4.0/2.7/7.4/1.2 pCi/L (ave/min/max/std.dev). Collocated CC measurements carried out over the period 12/7/87 to 12/9/87 gave results of 1.8 and 2.1 pCi/L in the crawl space and 2.1 and 2.2 pCi/L in the living room.

Diagnostic measurements of the pressure field extension in the soil were carried out with only two pits active, and with all four pits under suction. The results of these measurements along with the results of similar measurements carried out at House DW84 will be discussed in Section 7.

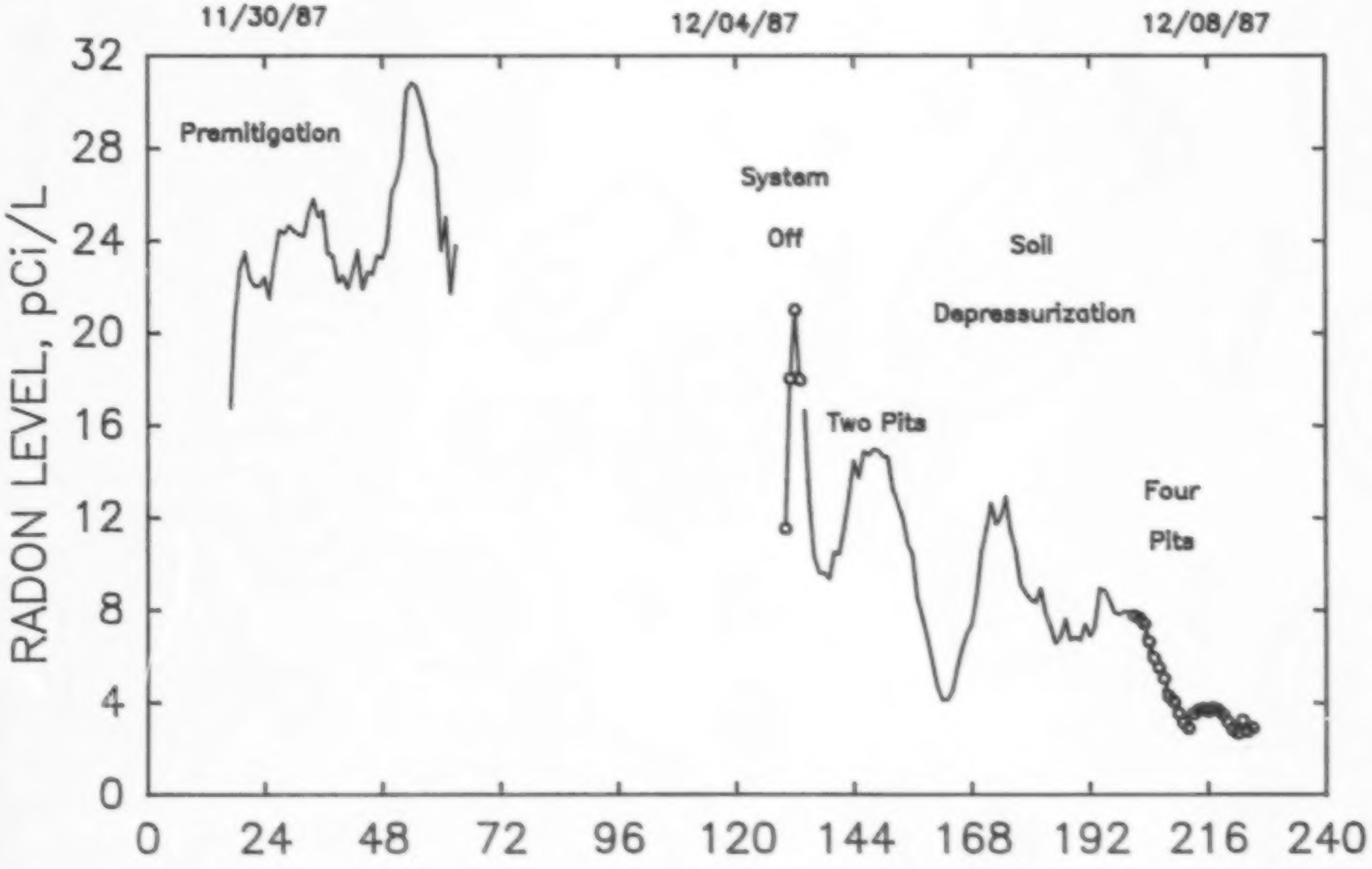


Figure 30. House DW31 continuous radon levels in den.

No additional mitigation work is expected to be carried out on this house. Because of the high costs of attempting to seal the openings between the crawl space and the living areas of the house, Phase 2 (IDCS) was not implemented. Long-term alpha track detectors were installed on 12/9/87 and will be replaced quarterly for the next 2 years.

House DW60

This house is a crawl space house with a slab-on-grade garage attached to and in open communication with the living areas (the garage has been converted into a work-study/den). The crawl space had some poly vapor barrier installed initially. The floor between the crawl space and the upstairs was insulated and some of the water pipes in the crawl space were wrapped with closed-cell foam. The heating system for the house is by electrical resistance strip heaters in the baseboard. The only cooling equipment are two window mounted air conditioners. There are no ducts in the crawl space.

Pre-mitigation Evaluation--

Pre-mitigation monitoring with the CRM was carried out over the period 12/1/87 to 12/3/87. The resultant radon levels in the living room over this period were 28.7/21.7/32.3/2.4 pCi/L (ave/min/max/std.dev). Collocated CC measurements carried out over this same time period gave values of 55.0 and 55.2 pCi/L in the crawl space and 27.8 and 27.9 pCi/L in the living room. The latter values agree quite well with the CRM results in the living room. The CRM readings for this house are shown in Figure 31, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

The Phase 1 (IVCS) mitigation designed for this house was to isolate and ventilate the crawl space, thus removing the radon gas before it can move into the living areas. The Phase 2 (SPD) mitigation plan was to install a sub-poly depressurization system in the crawl space. To keep installation costs as low as possible, both phases of the mitigation plans were installed at the same time. Also, the existing poly sheeting in the crawl was used and supplemented where necessary to cover the exposed soil. Both phases of the mitigation plans were installed over the period 12/3/87 to 12/6/87.

Phase 1 (IVCS) Evaluation--

Beginning on 12/6/87 the sub-poly fan was left unenergized and the results of sealing the openings between crawl and living areas was evaluated. During this evaluation, two block vents on opposite sides of the house were left open, and the remaining vents were closed. The CRM results measured in the living room over the period 12/6/87 to 12/8/87 were 21.0/6.4/31.8/6.1 pCi/L (ave/min/max/std.dev). The average radon reduction achieved through sealing and passive ventilation was 27 percent.

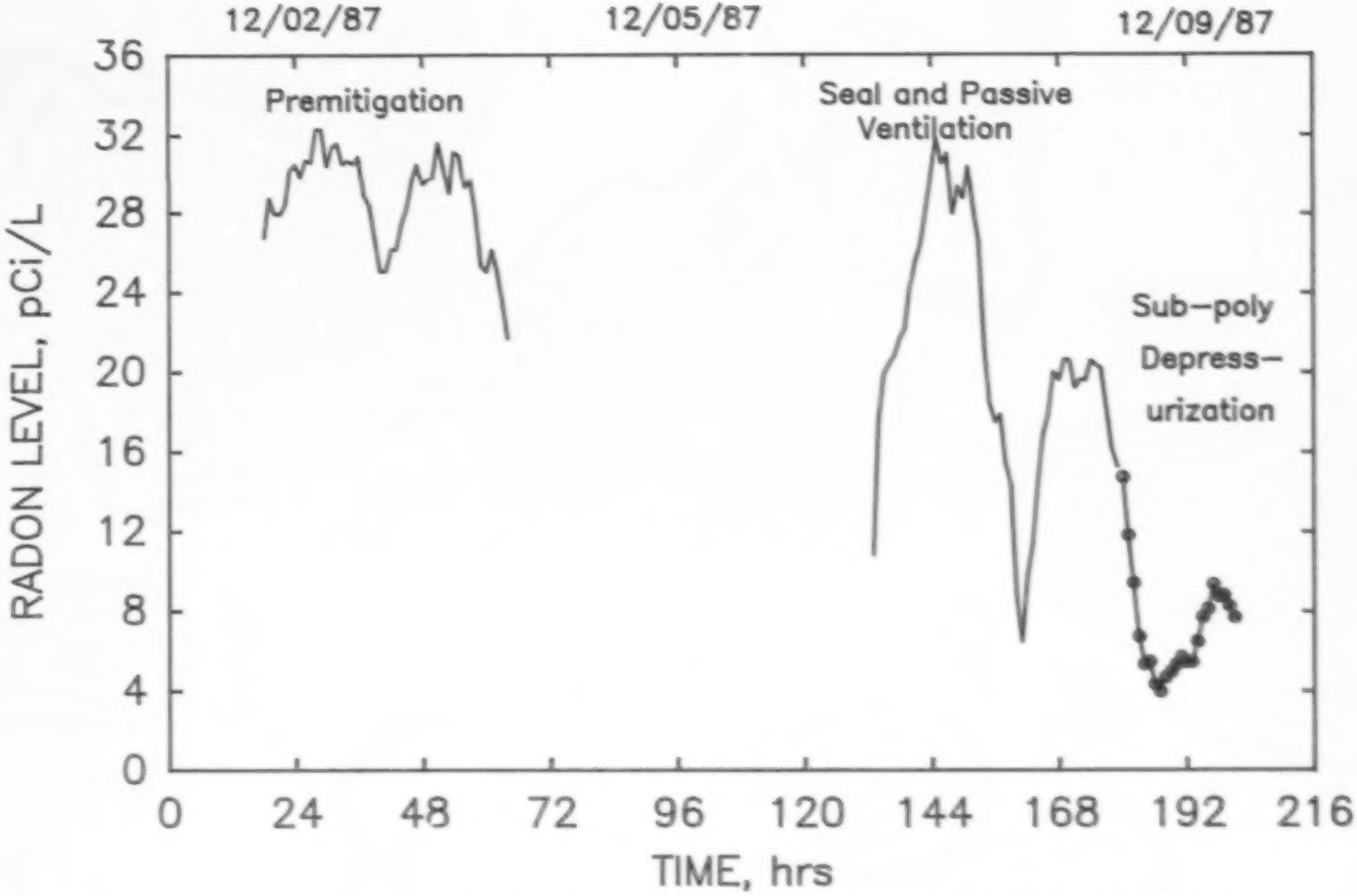


Figure 31. House DW60 continuous radon levels in living room.

Phase 2 (SPD) Evaluation--
The sub-poly suction fan was energized at 1300 hrs on 12/8/87. The results of the CRM in the living room over the period 12/8/87 to 12/9/87 were 6.6/4.0/9.4/1.7 pCi/L (ave/min/max/std.dev) which represents and average reduction in the radon level upstairs of 77 percent.

Subsequent collocated CC measurements carried out over the period 1/26/88 to 1/28/88 gave results of 23.1 and 23.4 pCi/L in the crawl space and 15.0 and 15.4 pCi/L in the living room. These readings represent a net reduction in the radon level of only 45 percent. Since these levels were still above the 4 pCi/L guideline, additional mitigation was required.

Phase 2A (IPCS) Evaluation--
Rather than installing a second suction point under the poly, it was decided to test the pressurization device (IPCS) (Current Indoor Air Systems Inc., model 300 "Kyle Lefkoff") originally scheduled for House DW82 (but never installed at DW82 because of equipment problems).

Attempts were made to evaluate the crawl space pressurization system in March 1988. The delay in testing this system was caused by a lack of continuous radon monitors. Unfortunately, the weather conditions were such that measurements had to be aborted. The wind loading on the house made it impossible to monitor the pressure differences between the crawl space and the outside. Also, the ambient temperatures were high enough that the homeowner refused to leave the house in a closed condition so reliable radon measurements were impossible. It is anticipated that the system will be evaluated under more favorable conditions in the Fall 1988. Long-term alpha track detectors were installed on 12/9/87 and will be replaced quarterly for the next 2 years.

House DW66

This house is a crawl space house with an adjoining slab-on-grade garage with numerous leaks between the house and the garage. The crawl space is not insulated from the living areas above, and there are HAC ducts located in the the crawl. The soil in the crawl space is approximately 50 percent covered with poly sheeting of poor condition.

Pre-mitigation Evaluation--
Pre-mitigation CRM monitor results carried out over the period 12/1/87 to 12/3/87 indicated the levels in the back bedroom were 11.7/8.5/14.6/1.5 pCi/L (ave/min/max/std.dev). These values compare well with collocated CC measurements carried out over the same time period. The CC results were 25.9 and 26.1 pCi/L in the crawl space and 11.9 and 12.3 pCi/L in the back bedroom of the house. The CRM readings for this house are shown in Figure 32, and a complete printout of the data is included in the Appendix.

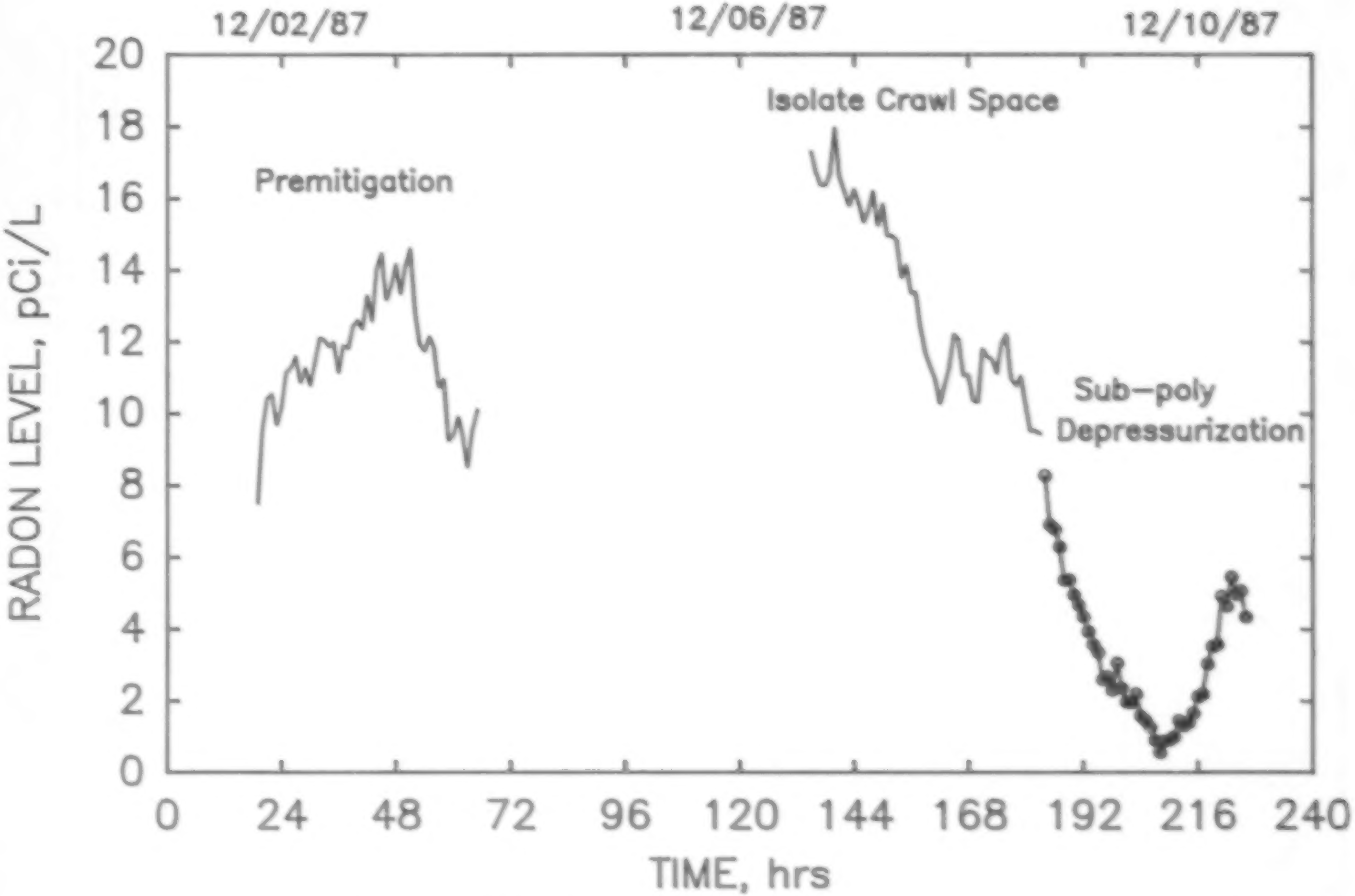


Figure 32. House DW66 continuous radon levels in back bedroom.

Mitigation Installation--

Both phases of the mitigation design were installed over the period 12/3/87 to 12/6/87. The Phase 1 (ICS) mitigation designed for this house was to seal the openings between the crawl space and the living areas in an effort to determine if sealing alone would reduce the radon levels. The Phase 2 (SPD) mitigation for this house was to install additional poly sheeting to completely cover the exposed soil and to install a single suction point under the poly with a fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) exhausting through a vent in the foundation wall. In installing the sub-poly system, the poly was not attached to the foundation walls nor to the support piers with the exception of those immediately adjacent to the suction point. Also, the sheets of poly were not sealed at the overlap but simply overlapped by about 12 inches. In order to reduce construction costs, both phases of the mitigation plans were installed at the same time but evaluated separately.

Phase 1 (ICS) Evaluation--

The evaluation of sealing alone was carried out over the period 12/6/87 to 12/8/87. The CRM values for this period were 13.4/10.2/18.0/2.4 pCi/L (ave/min/max/std.dev) as measured in the back bedroom. These numbers represent an increase in the radon levels of approximately 15 percent. Because of the short evaluation period (45 hours total), the increased levels measured in the bedroom may or may not be significant.

Phase 2 (SPD) Evaluation--

At 1412 hrs on 12/8/87 the sub-poly fan was energized. The CRM values measured in the back bedroom over the period 12/8/87 to 12/10/87 were 3.3/0.6/8.3/1.9 pCi/L (ave/min/max/std.dev). These values represent a reduction of about 62 percent based on the CRM results. Collocated CC measurements were carried out over the period 1/27/88 to 1/29/88 with the resultant values of 7.4 and 7.8 pCi/L in the crawl space and 2.7 and 2.8 pCi/L in the back bedroom of the house. These values represent a net radon reduction of 77 percent compared to the CC measurements done on 12/1/87.

No additional work is anticipated for this house. Long-term alpha track detectors were installed on 12/10/87 and will be replaced quarterly for the next 2 years.

House DW82

This crawl space house was one of the first group of houses mitigated during 1987. Because of the limited access areas in the crawl space, only techniques that treated the crawl space as a whole were designed for this house.

Pre-mitigation Evaluation--

On 11/29/87 collocated 48 hour pre-mitigation charcoal detectors were installed in both the crawl space and in the den of the house. The radon levels were found to be 29.5 and 30.0 pCi/L in the crawl space and 14.7 and 15.1 pCi/L in the den. Also on 11/29/87 a Pylon AB-5 passive radon monitor was installed in the den to continuously monitor the radon levels. The levels for the period 11/29/87 to 12/1/87 were 14.9/12.4/19.5/1.7 pCi/L (ave/min/max/std.dev). This average value agrees well with that from the CC measurements. The CRM readings for this house are shown in Figure 33, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

The Phase 1 (IPCS) mitigation plan for this house was to seal and pressurize the crawl space with a commercial device (Current Indoor Air Systems, Inc., model 300, "Kyle Lefkoff device"). However, because of insufficient amounts of ducting for the device and the inability to locate more locally, this mitigation technique was aborted (the device is currently installed in House DW60). The Phase 2 (IDCS) mitigation technique for this house was to seal all openings both to the outside and into the living areas and to depressurize the crawl space with a small fan. The mitigation installation was carried out over the period 12/2/87 to 12/3/87.

Phase 1A (IVCS) Evaluation--

Although this mitigation was not part of the original design for this house, it seemed like an ideal opportunity to obtain additional data regarding this technique. Starting at 1800 hrs on 12/3/87 the levels in the den were monitored with a CRM. During this period the depressurization fan was not energized, and block vents on opposite sides of the house were left open. The radon levels measured in the den over the period 12/3/88 to 12/4/88 were 23.9/12.1/30.0/5.3 pCi/L (ave/min/max/std.dev). These values represent an increase of about 60 percent over the pre-mitigation CRM values. This result appears to indicate that sealing the openings between crawl space and living areas is difficult to accomplish using simple "patch and fill" techniques. Additional comments regarding this technique will be found later in Section 7.

Phase 2 (IDCS) Evaluation--

At 1600 hrs on 12/4/87 the depressurizing fan was turned on at low speed with a flow rate of about 100 cfm. Within approximately 9 hours the radon levels in the den dropped to less than 2 pCi/L as seen in Figure 33. The continuous monitor located in the den was allowed to run for an additional 37 hours, during which time the radon levels were 1.4/0.05/6.3/1.1 pCi/L (ave/min/max/std.dev). Collocated CC measurements were carried out over the period 12/6/87 to 12/8/87 both in the crawl space and in the den. The values measured were 61.5 and 61.9 pCi/L in the crawl space and 0.6 and 0.7 pCi/L in the den. These values represent a reduction in the upstairs radon of 96 percent and an increase in the crawl space levels of 107 percent.

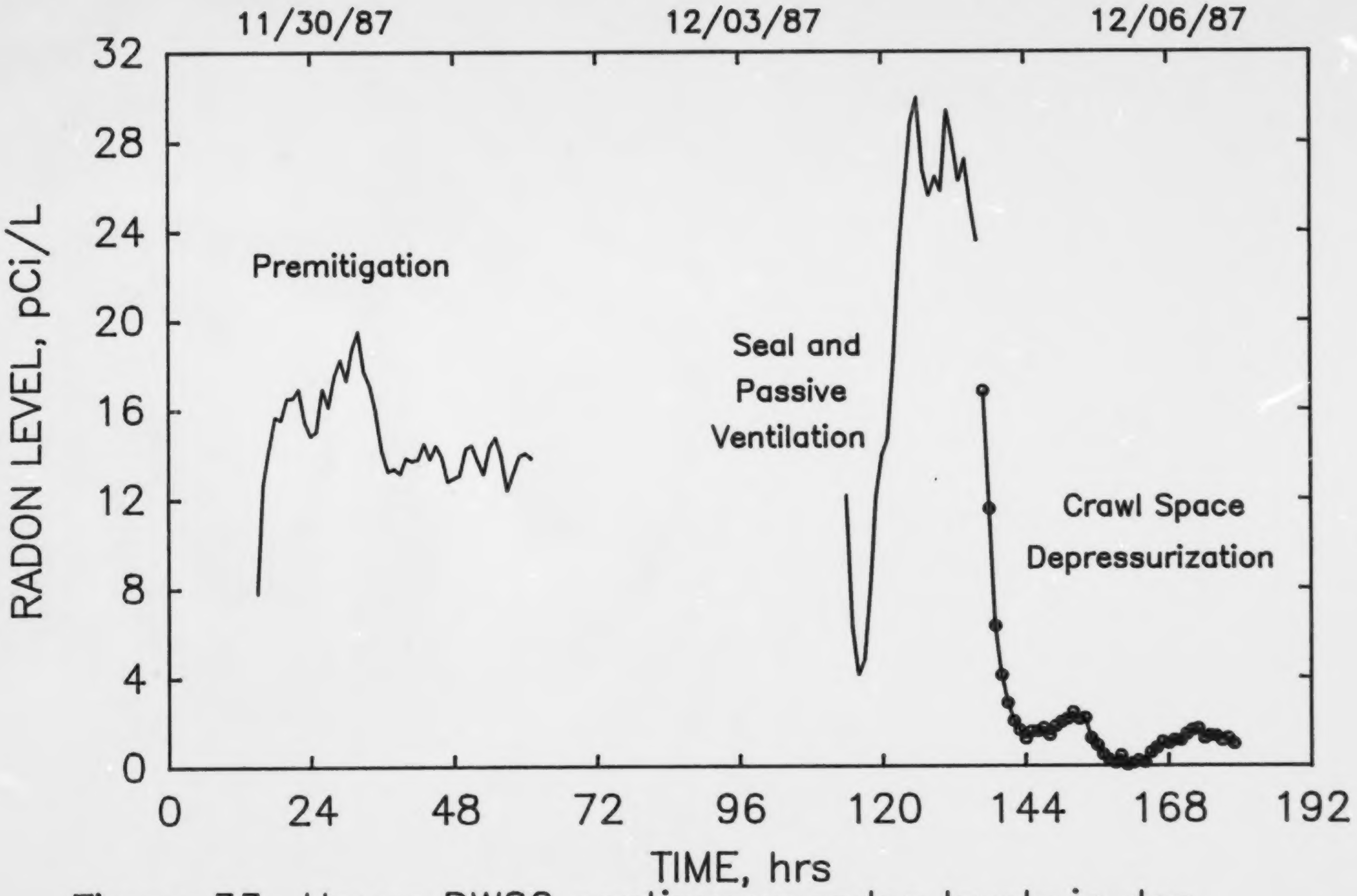


Figure 33. House DW82 continuous radon levels in den.

In an effort to quantitate the sealing and depressurization of the crawl space of this house, attempts were made to measure the pressure difference between the crawl and the outside air. Measurements were attempted using an electronic micromanometer (model EDM-I, Neotronics, Gainesville, GA) sensitive to about 0.001 inch of water. No pressure difference could be measured. By using smoke sticks to look for air leaks into the crawl space from the outside, it was discovered that there was definite and strong air flow into the crawl around each block vent. These leaks were due to gaps between the concrete blocks that had no mortar. Apparently, when the block wall foundation was built, the mortar joints were poorly constructed. These leaks could not be sealed from the inside as air flow was into the center of the blocks and then into the crawl space from numerous points. To effectively seal the block wall would have required extensive repointing of the joints between the blocks with mortar at each vent. The use of sealants or caulks was thought to be inappropriate and would be most noticeable against the wall background.

In effect the depressurization fan is pulling outside air into the crawl space and diluting and exhausting the radon levels in the crawl before the radon can get into the house itself. Also, it appears that the dilution occurs at some distance above the earth surface, thus resulting in elevated levels at ground level as indicated by the post-mitigation charcoal results. These detectors were placed on the ground approximately 15 feet from the fan inlet. It would be interesting to locate more charcoal detectors further away from the fan and 1 or 2 feet above the ground.

No further work is anticipated on this house. Long-term alpha track detectors were installed on 12/6/87 and will be replaced quarterly for the next 2 years.

House DW84

This house has exposed soil under the living areas with no poly covering the soil. The HAC ducts located in the crawl space are, in some locations, lying directly on the soil. The soil was relatively hard but contained large desiccation cracks up to 0.5 in. wide over most of the soil area.

Pre-mitigation Evaluation--

Both pre- and post-mitigation radon measurements made in this house are questionable because of the warm weather and the inability to keep the house closed both before and during the measurements. The pre-mitigation CC measurements carried out over the period 3/28/88 to 3/30/88 gave results of 9.4 and 9.7 pCi/L in the crawl space and 1.5 and 2.3 pCi/L in the living room (TABLE 12). The CRM values measured in the den over the period 3/28/88 to 3/30/88 were 2.1/0.0/4.3/1.3 pCi/L (ave/min/max/std.dev). These values agree somewhat with the CC values over the same period. The CRM readings for this house are shown in Figure 34, and a complete printout of the data is included in the Appendix.

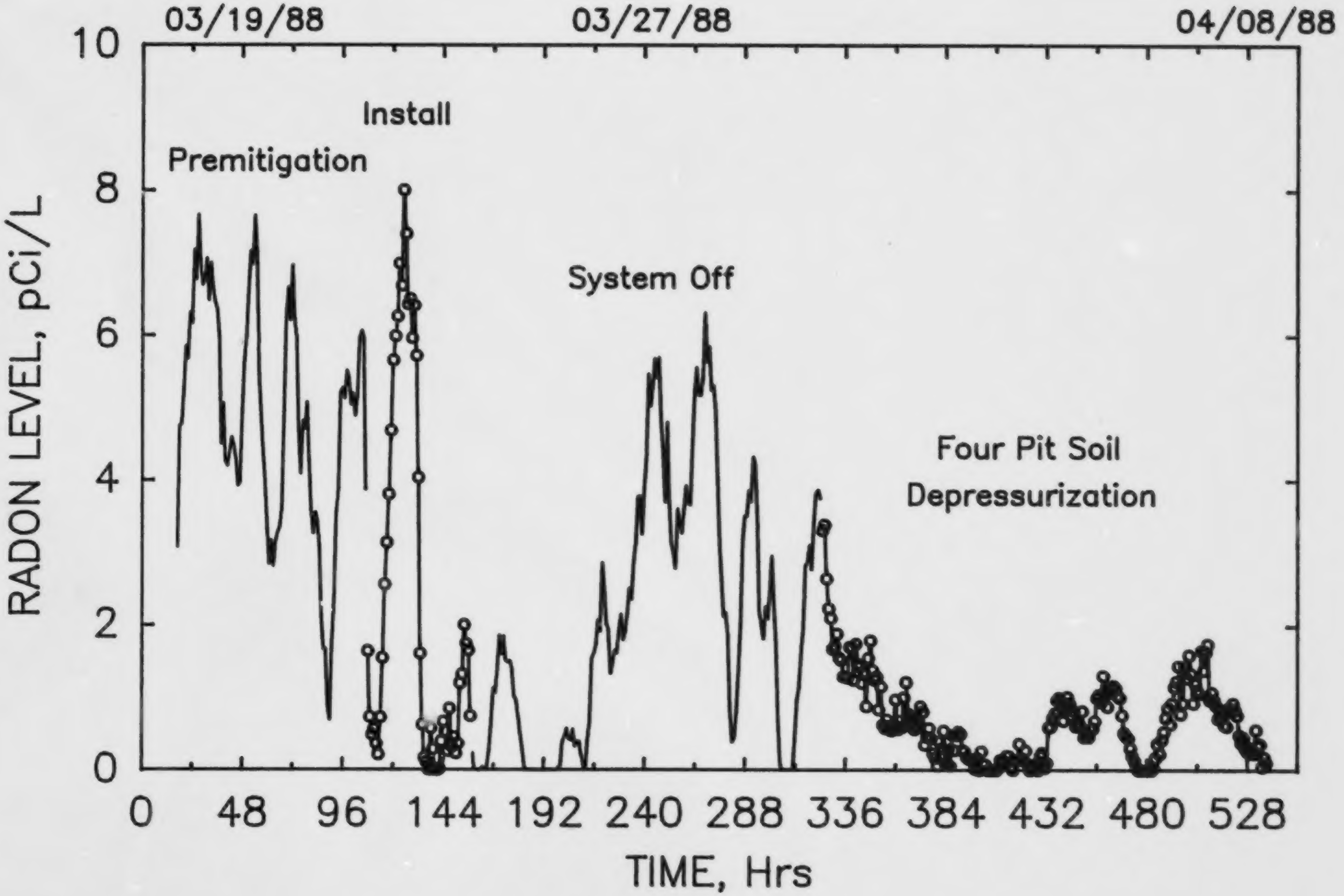


Figure 34. House DW84 continuous radon levels in living room.

Mitigation Installation--

The Phase 1 (SSoD) mitigation was installed in this crawl space house during the period 3/21/88 to 3/23/88. This included the construction of four pits in the crawl space soil, covering the pits with treated plywood, and connecting the pits with 4 in. PVC pipe to a single fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) exhausted through a block vent. Each of the pits was approximately 24 in. wide and 18 in. deep. Details of the suction pits were shown in Figure 8 above. The location of the suction pits are as shown in Figure 13 above.

Phase 1 (SSoD) Evaluation--

Post-mitigation CRM values measured in the den over the period 3/30/88 to 4/8/88 were 0.7/0.0/2.6/0.5 pCi/L (ave/min/max/std.dev). Because of the inability to insure that closed house conditions could be maintained, no post-mitigation CC measurements were carried out. A complete evaluation of the effectiveness of the mitigation efforts will not be available until the Fall of 1988. Pressure measurements were made in the soil at varying distances from the pits. The results from these measurements will be discussed in Section 7.

No further work is anticipated on this house. Long-term alpha track detectors were installed on 4/14/88 and will be replaced quarterly for the next 2 years.

House DW90

This house is a crawl space house with an attached slab-on-grade enclosed garage. There are two vents from the crawl space that open into the garage and constituted a significant radon entry point as the door between the house and garage is opened frequently and left open at times.

Pre-mitigation Evaluation--

Pre-mitigation CC measurements were carried out over the period 12/1/87 to 12/3/87. The results of these collocated detectors were 29.6 and 29.7 pCi/L in the crawl space and 15.8 and 15.8 pCi/L in the living room, as shown in TABLE 12 above. CRM results for the same time period in the living room were 15.8/7.2/23.6/4.1 pCi/L (ave/min/max/std.dev). These values agree quite well with the CC results. The CRM readings for this house are shown in Figure 35, and a complete printout of the data is included in the Appendix.

Mitigation Installation--

Both phases of the mitigation plans were implemented over the period 12/4/87 to 12/8/87. For Phase 1 (IVCS), the openings between the crawl space and the living areas were sealed as well as possible. In particular, the vents into the garage were sealed permanently using closed-cell, rigid foam board and urethane caulking. In addition to sealing the openings, the crawl space was passively vented using the existing block vents in the foundation wall to dilute and exhaust the radon gas before it entered the living areas.

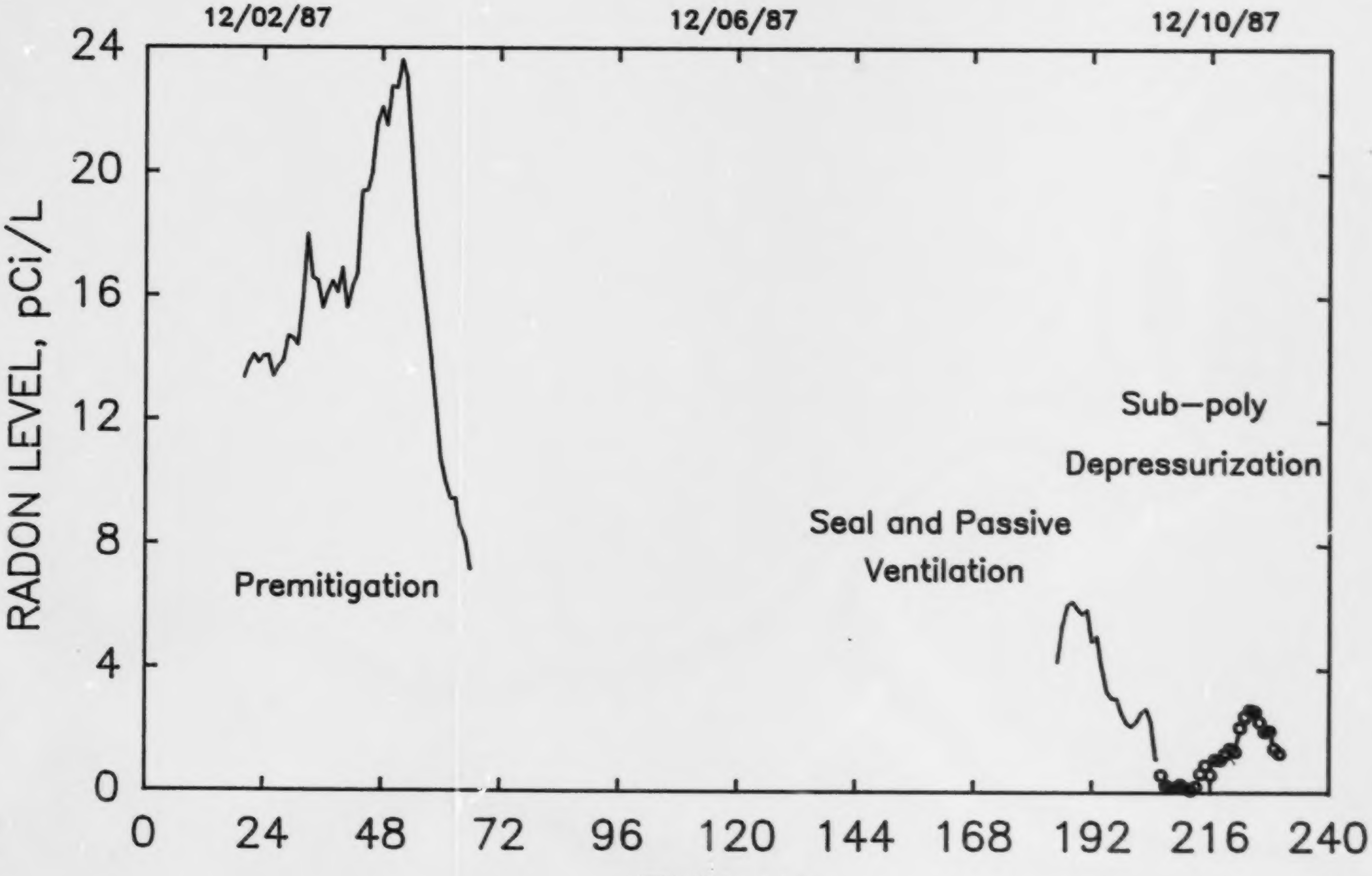


Figure 35. House DW90 continuous radon levels in living room.

The Phase 2 (SPD) mitigation supplemented the existing poly in the crawl space so that the exposed soil was completely covered. A single suction point was installed under the poly at a point near the center of the crawl space as shown in Figure 14 above. An inline fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) was installed in the crawl space with the exhaust through an existing block vent.

Phase 1 (IVCS) Evaluation--

Evaluation of the sealing and passive ventilation method of radon control was carried out over the period 12/8/87 to 12/9/87. The results as determined with the CRM located in the living room were 4.0/2.2/6.2/1.5 pCi/L (ave/min/max/std.dev). Although the evaluation period was extremely short, the 75 percent reduction achieved was the highest of any of the seal and passive ventilation installations.

Phase 2 (SPD) Evaluation--

The sub-poly fan was energized at 1400 hrs on 12/9/87. The CRM results in the living room for the period 12/9/87 to 12/10/87 were 1.2/0.1/2.7/0.8 pCi/L (ave/min/max/std.dev), which corresponds to a reduction of about 92 percent for the sub-poly depressurization technique. Subsequent CC measurements carried out over the period 1/26/88 to 1/28/88 indicated the radon levels were 7.0 and 7.1 pCi/L in the crawl space and 2.2 and 2.5 pCi/L in the living room. These values represent a reduction of approximately 85 percent.

No additional work is anticipated on this house. Long-term alpha track detectors were installed on 12/10/87 and will be replaced quarterly for the next 2 years.

BASEMENT HOUSES CONVERTED FROM CRAWL SPACES

House DW43

This house has a basement excavated from a crawl space. Although there are no exposed soil areas in the basement, the slab has numerous cracks that serve as radon entry points. Also, the perimeter of the basement has a cement capped shelf approximately 3 feet wide and about 4 feet above the basement floor. The shelf wall is constructed of coarse cinder blocks in direct communication with the soil.

Pre-mitigation Evaluation--

Pre-mitigation CRM results taken in the basement over the period 11/29/87 to 12/1/87 were 46.2/41.7/50.5/2.2 pCi/L (ave/min/max/std.dev). Collocated CC measurements over this same period were 58.6 and 59.7 pCi/L in the basement and 22.9 and 23.3 pCi/L in the upstairs bedroom. The CRM readings for this house are shown in Figure 36, and a complete printout of the data is included in the Appendix.

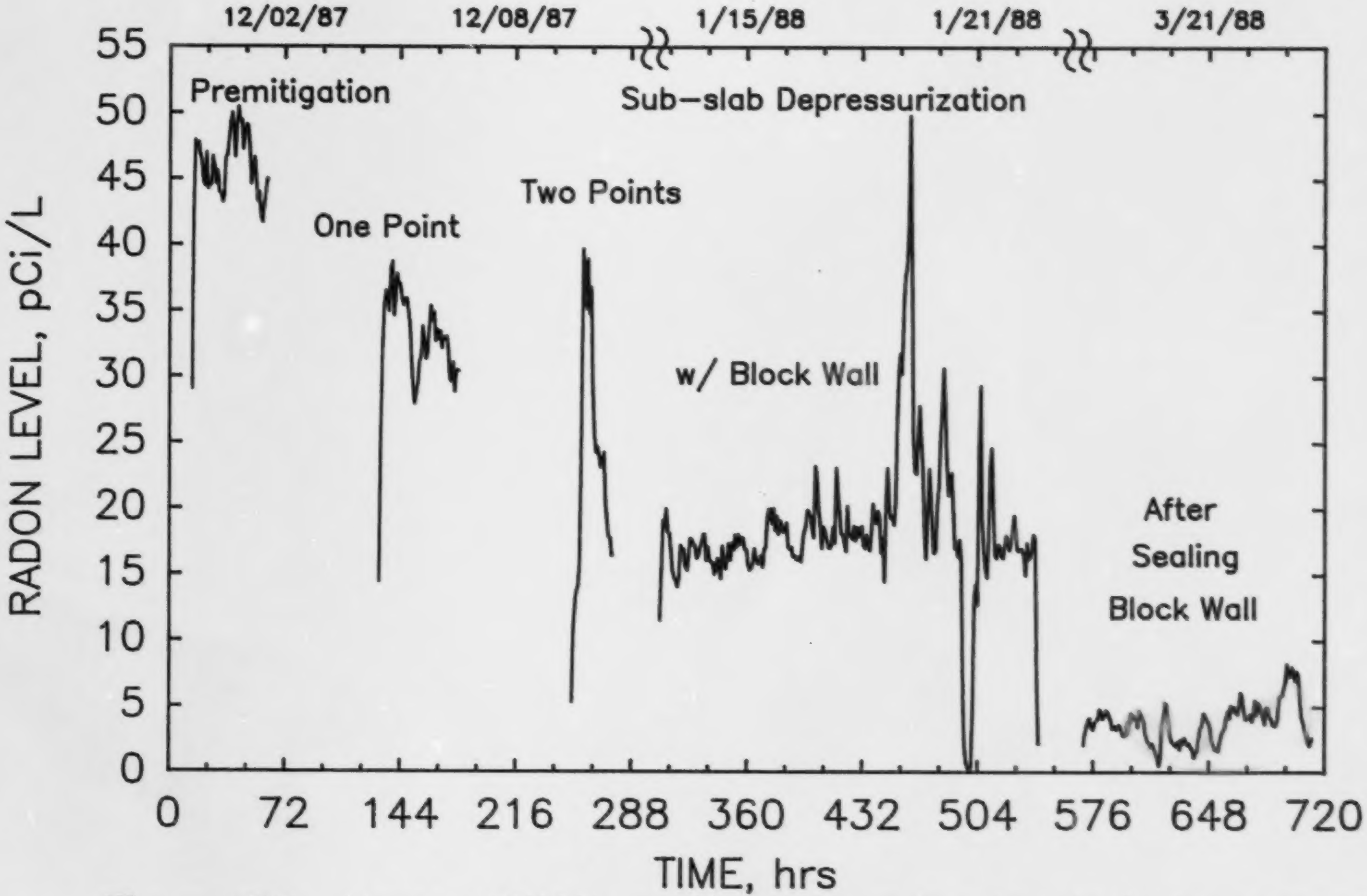


Figure 36. House DW43 continuous radon levels in basement.

Mitigation Installation--

The Phase 1 (SSD-N) and Phase 2 (SSD-W) mitigation designs for this house were to install two-point sub-slab depressurization systems. The soil under each of the slab penetrations was to be excavated in first a deep, narrow hole (4 inches wide by 28 inches deep) and then into a wide, shallow hole (24 inches wide by 10 inches deep). The relative merits of each suction hole shape were to be evaluated by measuring the pressure field extension resulting from each configuration. The Phase 3 (SSBWD) mitigation plan was to incorporate block wall suction if necessary to lower the radon levels below 4 pCi/L. The first phase of the mitigation, a two-point sub-slab suction system, was installed during the period 12/1/87 to 12/4/87.

Phase 1 (SSD-N) and Phase 2 (SSD-W) Evaluations--

Measurements of the pressure field extension with the two pit configurations showed very little difference, with the wide pit giving a marginally better pressure (actually a depressurization) at test points located close to the suction point. In general, communication under the slab was poor. In reflection, part of this poor pressure field extension could have been due to the porous block walls located next to the sub-slab suction points. Much of the pressure was lost to the face of the wall prior to sealing. The shape of the sub-slab suction pits was left as a combination of a shallow, wide pit with a narrow, deep hole in the center. The pressure field extension as a function of the suction pit size will be discussed in more detail in Section 7 along with similar measurements at other houses.

Evaluation of the radon reduction achieved with a single-point sub-slab system was carried out briefly over the period 12/4/87 to 12/6/87. The results were evaluated using a CRM located in the basement and are shown in Figure 36. The radon levels recorded over this time period were 33.4/27.9/38.8/2.7 pCi/L (ave/min/max/std.dev). This represents a reduction of approximately 28 percent over the pre-mitigation CRM results.

Phase 3 (SSBWD) Evaluation--

Based on the small reduction achieved with a single suction point and the lack of pressure field extension under the slab, it was decided to add a second suction point on the opposite side of the basement and also to connect the suction system to the block wall. This was carried out over the period 12/6/87 to 12/9/87. Evaluation of the two-point sub-slab plus wall depressurization system was carried out briefly over the period 12/9/87 to 12/10/87. For this short period the radon levels in the basement were 27.0/16.4/39.8/7.4 pCi/L (ave/min/max/std.dev). Evaluation was discontinued because of time and equipment until January 1988.

The CRM was reinstalled in the basement of House DW43 over the period 1/12/88 to 1/22/88. For this period the two-point sub-slab, plus block wall, depressurization system was operating with the fans at maximum speed. The flow rate from each fan was less than 25 cfm. The radon levels (shown in Figure 36) measured by the CRM in the basement over this period were 18.5/0.1/49.9/5.6 pCi/L (ave/min/max/std.dev). It was apparent that both the flow and the pressure field under the slab were being short-circuited. The most likely source of problem was the walls of the basement shelf. By holding a smoke source next to the wall surface, smoke could be seen to enter the face of the porous cinder block. This could be demonstrated for several feet away from the wall suction points. This was corrected by coating the block wall with a surface bonding, cement mixture of Portland cement and glass fibers (Sakrete Products, Surewall product). This was completed on 1/27/88.

The effects of sealing the wall were evaluated over the period 3/17/88 to 3/23/88 using a CRM located in the basement. The radon levels measured in the basement over this period were 3.8/0.5/8.3/1.5 pCi/L (ave/min/max/std.dev). These values represent a reduction of 92 percent relative to the pre-mitigation CRM values recorded in November 1987. The radon reduction was confirmed by collocated CC measurements carried out over the period 3/21/88 to 3/23/88. These values were 4.7 and 4.8 pCi/L in the basement and 1.4 and 1.4 pCi/L in the upstairs bedroom. When compared to the pre-mitigation CC measurements (see TABLE 12) done in November-December 1987, these levels represent a 92 percent reduction in the basement and a 94 percent reduction upstairs.

No additional work is expected on this house. Long-term alpha track detectors were installed on 12/10/87 and will be replaced quarterly for the next 2 years.

House DW78

DW78 is a basement house excavated out of the crawl space. The area of exposed dirt in the basement is approximately equal to the area of concrete slab.

Pre-mitigation Evaluation--

Pre-mitigation collocated CC measurements were carried out over the period 2/19/88 to 2/22/88. These results were 41.2 and 41.5 pCi/L in the basement and 19.6 and 19.9 pCi/L upstairs in the study. No CRM was available to monitor the radon levels prior to mitigation installation.

Mitigation Installation--

During the period 2/22/88 to 2/26/88, the Phase 1 mitigation was installed. This included two sub-slab depressurization points in opposite corners of the basement. Two fans were used because of difficulties in locating the piping for a single fan. No continuous radon monitor was available at the time of installation. Following installation, the fans were left unenergized until a monitor became available during the month of March 1988.

A CRM was placed in the basement on 3/4/88 with the suction fans off to obtain a pre-mitigation background. These levels over the period 3/4/88 to 3/7/88 were 34.0/29.1/39.4/2.4 pCi/L (ave/min/max/std.dev). These values were lower than the pre-mitigation CC measurements of 2/19/88 and could be attributed to differences in ambient weather conditions and to the fact that the cracks in the basement floor were sealed when the sub-slab systems were installed on 2/22/88. The CRM readings for this house are shown in Figure 37, and a complete printout of the data is included in the Appendix.

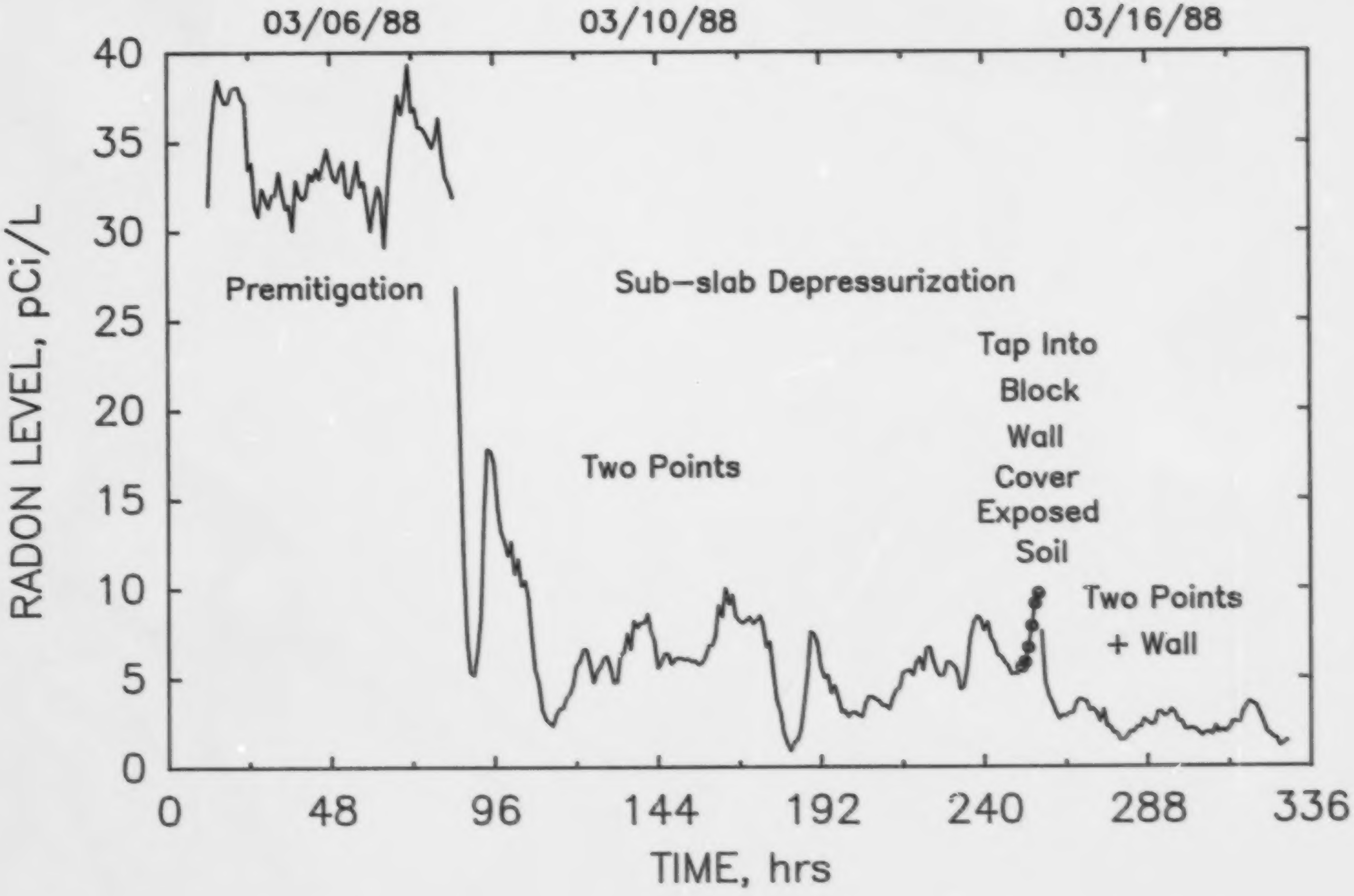


Figure 37. House DW78 continuous radon levels in basement.

Phase 1 (SSD-N) and Phase 2 (SSD-W) Evaluations--

The fans were turned on at 1215 hrs on 3/7/88, and the sub-slab pressure field extension was measured as a function of the suction pit shape. A significant improvement in the sub-slab pressure levels was observed with the wide pit as compared to that generated with the narrow pit. The details of these measurements will be discussed in more detail in Section 7.

The radon levels in the basement were monitored with the CRM over the period 3/7/88 to 3/14/88. The levels for this period were 6.3/0.9/17.8/2.9 pCi/L (ave/min/max/std.dev). Since these were still above the target level of 4 pCi/L, it was decided to proceed with the Phase 3 (SSBWD) mitigation by tapping into the concrete block walls with the sub-slab system. Also, at this time the Phase 4 (SSSPD) mitigation system was installed. This included covering the exposed soil in the basement with 6 mil polyethylene and attaching it to the block walls. This was carried out over the period 3/14/88 to 3/15/88.

Phase 3 (SSBWD) and Phase 4 (SSSPD) Evaluations--

By extending the fan suction systems into the block wall, and attaching the poly covering the soil to the top of the interior wall, the suction system was extended through the walls and to the soil itself. This installation was carried out in this manner because of the high porosity of the blocks and the large area of exposed soil in the basement. It was thought that little would be gained by depressurizing the sub-slab and block wall areas with out covering the soil.

CRM measurements carried out in the basement over the period 3/15/88 to 3/17/88 resulted in radon levels in the basement of 2.3/1.1/3.6/0.6 pCi/L (ave/min/max/std.dev). These results indicate that the combined mitigation system is effectively controlling the radon entry into the house. CC measurements over this same period gave values in the basement of 2.7 and 2.9 pCi/L and upstairs in the den of 1.5 pCi/L.

No additional mitigation is anticipated for this house except to reevaluate the sealing between the poly and the block wall. There is some concern about the reliability of the technique used to attach the poly to the block walls. Because of the narrow width of the blocks, and the ease with which they could be shattered, no masonry fasteners were used. The poly was attached to the blocks with one-part urethane caulking alone. The system will be inspected at a later time to determine if additional measures need to be taken to improve the mechanical strength of the joint between the poly and the block walls. Long-term alpha track detectors were installed on 3/23/88 and will be replaced quarterly for the next 2 years.

COMBINATION BASEMENT/CRAWL SPACE HOUSES

House DW12

DW12 is a basement house with a small crawl space containing exposed soil open to the basement. Since the area of exposed soil in the crawl space is small relative to the total area of the basement (about 15% exposed soil area), it was thought that the soil might be only a minor contributor to the radon entry into the basement. In the initial mitigation of the house, the soil was not given a high priority compared to the basement slab.

Pre-mitigation Evaluation--

A continuous monitor was installed in the basement on 2/5/88 and remained in place until 2/19/88. The pre-mitigation levels as indicated by the CRM were 11.9/6.5/18.2/3.7 pCi/L (ave/min/max/std.dev) over the period 2/5/88 to 2/8/88. The CRM readings for this house are shown in Figure 38, and a complete printout of the data is included in the Appendix. Collocated CC measurements over this same period (as shown in TABLE 12) indicated the radon levels to be 10.3 and 11.8 pCi/L in the basement and 7.7 and 7.8 pCi/L in the living room upstairs.

Mitigation Installation--

The Phase 1 (SSD-P) mitigation was installed over the period 2/8/88 to 2/10/88. This included a two-point sub-slab suction system. Because of difficulties involved in trying to use a single fan for both suction points, two fans were installed. The exposed soil in the crawl space was covered with 6 mil polyethylene sheeting. Little or no sealing of the sheets to the wall was achieved. No active ventilation system was installed to depressurize the soil under the poly during the initial installation. However, provisions were made during installation so that a sub-poly depressurization system (the Phase 2 mitigation strategy) could be installed at a later time if it became necessary.

Phase 1 (SSD-P) Evaluation--

During installation of the suction holes and fans, progressively larger holes in the sub-slab soil were tested. Testing of each hole size was carried out by monitoring the air pressure difference (Δp) between the sub-slab area and the basement at a series of small test holes drilled in the basement slab. The location of these test holes are shown in Figure 22 above. Measurements of the Δp at these test holes indicated that with no soil excavated from under the slab almost no pressure field was developed under the slab. With a hole of approximately 10 inches wide and 8 to 12 inches deep, the Δp values were as high as -0.054 inches of water at a distance of approximately 10 ft from the suction hole. At more distant points, the Δp was less, but still measurable at most of the test points. Very little improvement was achieved by further enlarging the hole size. Details of these measurements will be discussed in Section 7.

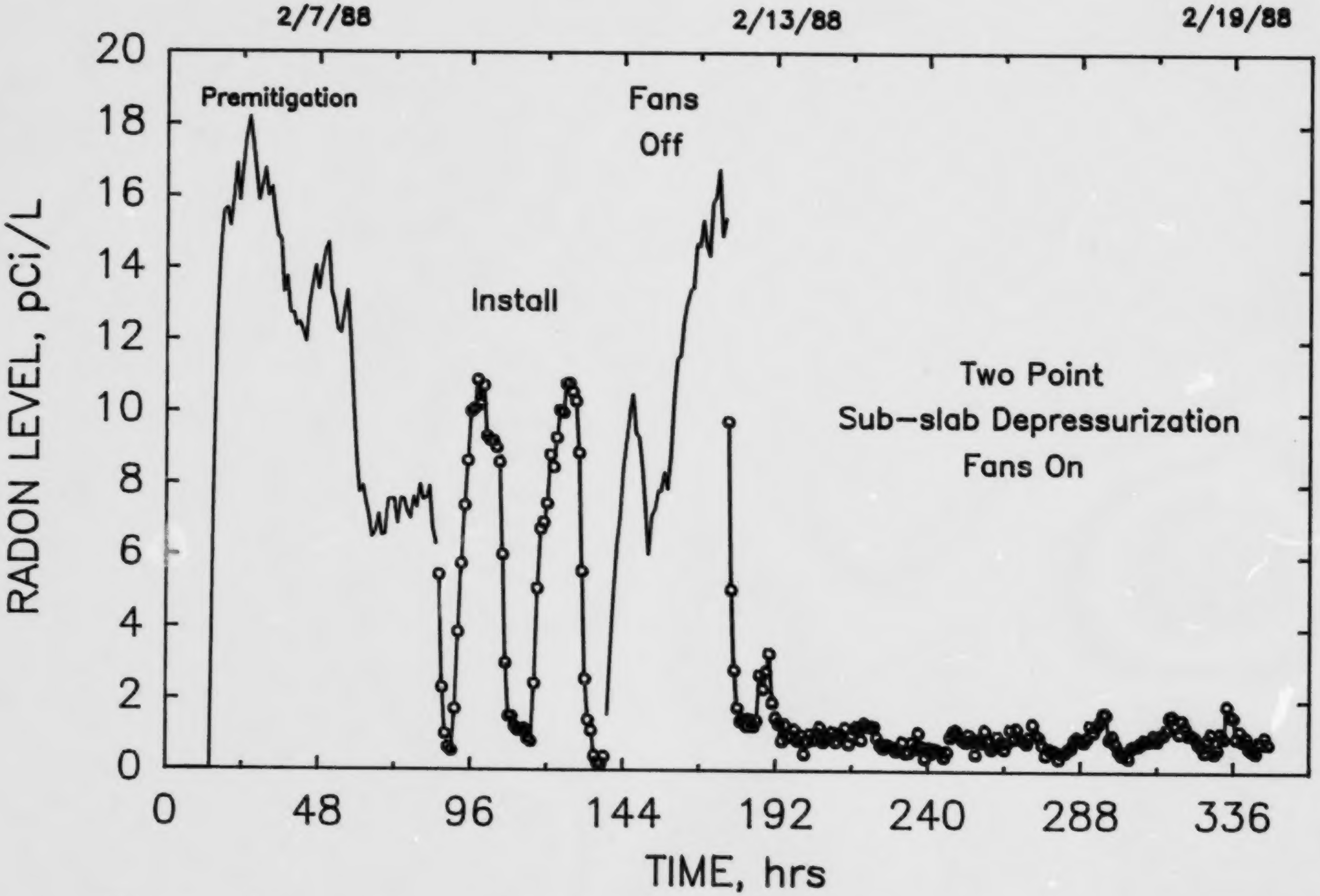


Figure 38. House DW12 continuous radon levels in basement.

Installation of the SSD systems was completed on 2/10/88. The sub-slab suction fans were left off until 2/12/88 in order to reestablish a pre-mitigation background level. Over this period, 2/11/88 to 2/12/88, the radon levels in the basement were 11.2/6.0/16.8/3.2 pCi/L (ave/min/max/std.dev). These values are very near the pre-mitigation levels (described above) that were measured before starting the mitigation installation.

Both fans were energized on 2/12/88, and the levels in the basement were monitored over the period 2/12/88 to 2/19/88. The post-mitigation levels as measured with the CRM were 1.0/0.4/3.3/0.4 pCi/L (ave/min/max/std.dev). These levels represent a reduction of approximately 92 percent compared to the pre-mitigation levels measured with the CRM in the basement.

Post-mitigation collocated CC measurements were carried out over the period 3/1/88 to 3/3/88 with the resultant values of 4.3 and 4.4 pCi/L in the basement and 4.5 and 5.0 pCi/L in the living room. Although these values are slightly above the 4 pCi/L guideline, it was decided to evaluate the system over a longer period of time before any additional mitigation work was carried out. Long-term alpha track detectors were installed on 3/1/88 and will be replaced quarterly for the next 2 years. The final evaluation of this house will be carried out after one or more of the ATDs have been analyzed.

House DW14

DW14 is full basement house, with a small area (280 ft^2) of exposed soil (a crawl space) in the basement. The basement is unfinished and used mainly as a storage and workshop area. It was estimated during the mitigation design that the crawl space could represent a significant radon source into the basement. This estimate was based in part on the absence of cracks and openings in the slab itself. Consequently, the crawl space would likely have to be mitigated before the radon levels in the house could be reduced to acceptable levels.

Pre-mitigation Evaluation--

No continuous monitor was available at the time work was begun on this house. Pre-mitigation collocated CCs were placed both in the basement and the upstairs den during the period 2/8/88 to 2/10/88. The values obtained were 86.7 and 89.8 pCi/L in the basement and 47.1 and 48.1 pCi/L upstairs.

Mitigation Installation--

During the period 2/10/88 to 2/12/88 the Phase 1 (SSD-P) mitigation system, a two point, two fan, sub-slab depressurization system was installed. Sub-slab Δp measurements made during installation showed that the sub-slab pressure field was substantially improved by enlarging the hole under the slab at the suction point. For example, with no suction pit under the slab the Δp values were practically unmeasurable, whereas with a large pit the values were generally in the range of -0.005 to -0.09 inches of water at distances of 8 ft from the suction point, and -0.001 to -0.005 inches of water at distances up to 55 ft from the suction hole. The Δp measurements as a function of suction pit size will be discussed in more detail in Section 7.

The exposed soil in the corner of the basement was covered with 6 mil polyethylene sheeting. The edges of the sheeting were attached to the foundation walls with wood strips and anchor studs. The tops of the block wall separating the crawl space and the basement were sealed with closed-cell expanding foam. Installation was completed on 2/12/88, and the fans were left running to reduce the exposure to the homeowner.

Phase 1 (SSD-P) Evaluation--

On 2/19/88 a continuous monitor became available and was installed in the basement. The fans were turned off at this time to allow the radon levels to return to pre-mitigation levels. The levels with the fans off for 72 hours (over the period 2/19/88 to 2/22/88) were 54.1/31.6/65.3/8.5 pCi/L (ave/min/max/std.dev). These values represent only about 60% of the values measured with the pre-mitigation CCs over the period 2/8/88 to 2/10/88. The fact that the crawl space was covered with poly sealed to the foundation walls may well account for the lower values. The CRM readings for this house are shown in Figure 39, and a complete printout of the data is included in the Appendix.

The fans were turned back on at 1424 hrs on 2/22/88, and the radon levels were monitored over the period 2/22/88 to 2/26/88. The levels in the basement with two sub-slab suction systems operating were 16.3/4.1/24.1/4.8 pCi/L (ave/min/max/std.dev). This represents a reduction of approximately 70% but was still well above the 4 pCi/L target level.

It was decided at that time, that the Phase 2 (SSBWD) and Phase 3 (SSSPD) mitigation techniques would have to be installed. This consisted of tapping into the block walls of the foundation and through the wall separating the soil from the basement. In the latter case the 4 inch PVC pipe was inserted through the block wall and into the soil underneath the poly covering.

Phase 2 (SSBWD) and Phase 3 (SSSPD) Evaluation--

After adding the wall depressurization to the sub-slab system, the levels in the basement as measured with the CRM over the period 2/26/88 to 3/2/88 were 8.3/2.8/12.6/2.6 pCi/L (ave/min/max/std.dev). These levels represent a reduction of 85 percent from the pre-mitigation levels. However, the levels were still above the desired value.

Investigations with a smoke bottle showed that a significant amount of basement air was being drawn in through the tops of the crawl space wall and around the edges of the poly covering the soil. A treated 2 x 12 inch board was sealed to the wall top, and the poly was sealed more tightly to the block walls. These touch-up measures were carried out on 3/2/88.

The CRM results in the basement over the period 3/3/88 to 3/4/88 were 3.93/1.8/7.2/1.5 pCi/L (ave/min/max/std.dev) or a 93 percent reduction. These levels in the basement were deemed satisfactory so that continuous monitoring was terminated. Collocated CCs were installed over the period 3/4/88 to

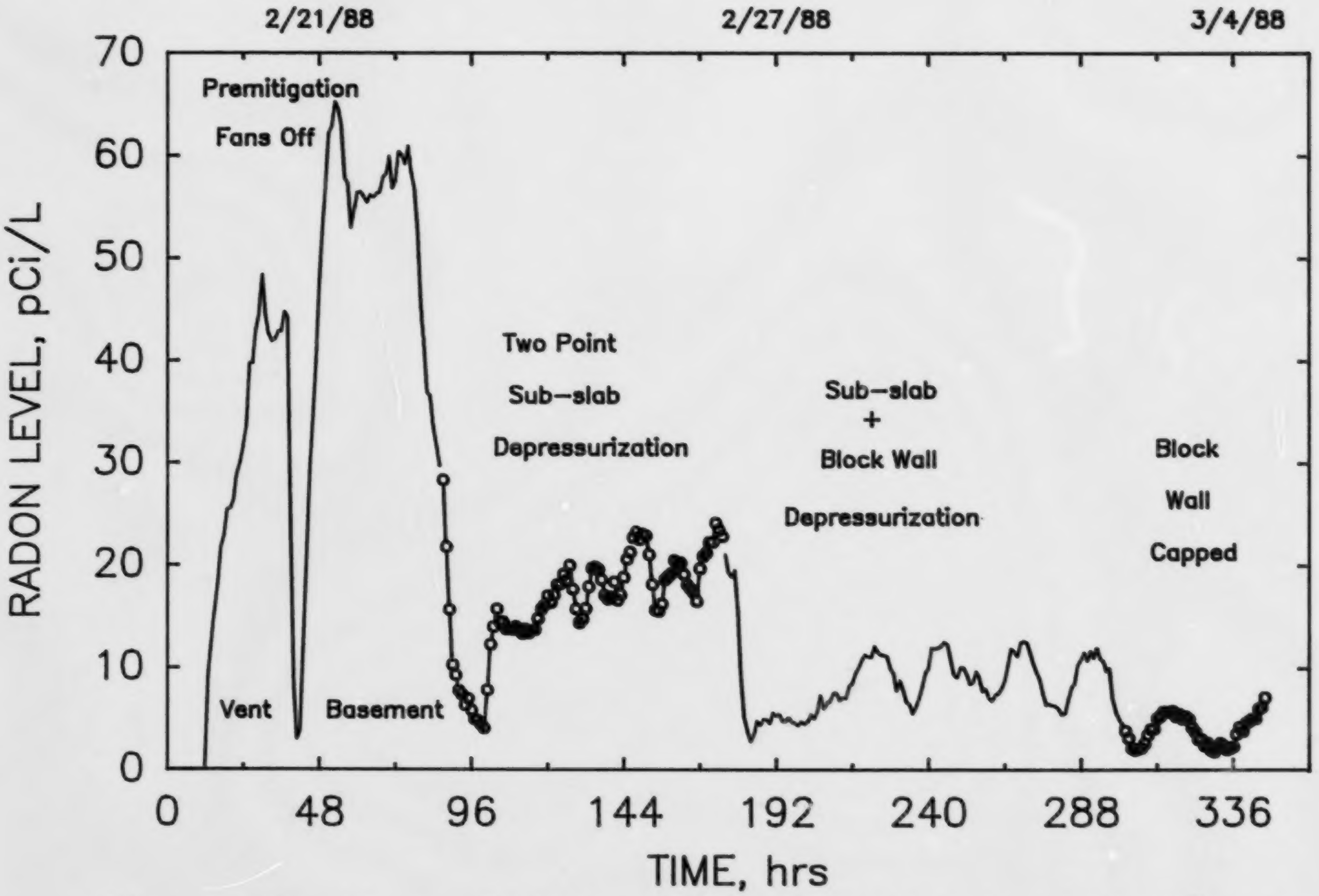


Figure 39. House DW14 continuous radon levels in basement.

3/7/88 in both the basement and the upstairs den. The results from these measurements were 11.1 and 11.4 pCi/L in the basement and 3.7 and 3.8 pCi/L in the den. The readings in the den were acceptable, but those in the basement were much higher than those recorded by the CRM. Upon investigation it was found that the CCs in the basement were placed on top of the wall separating the crawl space. Two more CCs were exposed in the basement over the period 3/21/88 to 3/23/88. These detectors were located about six feet out from the crawl space wall and approximately four feet above the basement floor in about the same location that the CRM was placed. The results after analysis were 2.9 and 3.0 pCi/L, in better agreement with the previous CRM results.

It appears that the region at the top of the wall is a localized hot spot. However, the amount of radon entering the basement is not high enough to raise the overall levels in the basement or the living areas above. It was decided to reevaluate the situation after the results of the long-term monitors were available. Long-term alpha track detectors were installed on 3/4/88 and will be replaced quarterly for the next 2 years.

SLAB-BELOW-GRADE HOUSES

House DW41

DW41, a finished basement house, was mitigated and evaluated during January and February 1988. Additional testing for termiticide in the basement was carried out to determine if the mitigation systems exacerbated the insecticide levels in the house.

Pre-mitigation Evaluation--

Pre-mitigation monitoring was carried out over the period 1/22/88 to 1/27/88 using a CRM located in the downstairs study. The radon levels recorded over this period were 17.9/10.1/31.7/4.4 pCi/L (ave/min/max/std.dev). Collocated CC measurements were carried out over a portion of this period, 1/22/88 to 1/25/88, and gave levels of 19.2 and 19.3 pCi/L in the lower study and 13.3 and 14.4 pCi/L in the upstairs den. The CRM readings for this house are shown in Figure 40, and a complete printout of the data is included in the Appendix.

Because of concern regarding the possibility of raising the levels of the termiticide (Aldrin) inside the house, gas samples were taken in two rooms of the basement on 1/22/88, before construction began. Analysis showed that the levels of Aldrin in these two rooms were 0.3 and 0.12 $\mu g/m^3$.

Mitigation Installation--

Installation of the Phase 1 (SSP) mitigation system was carried out during the week of 1/25/88. This included covering the exposed soil

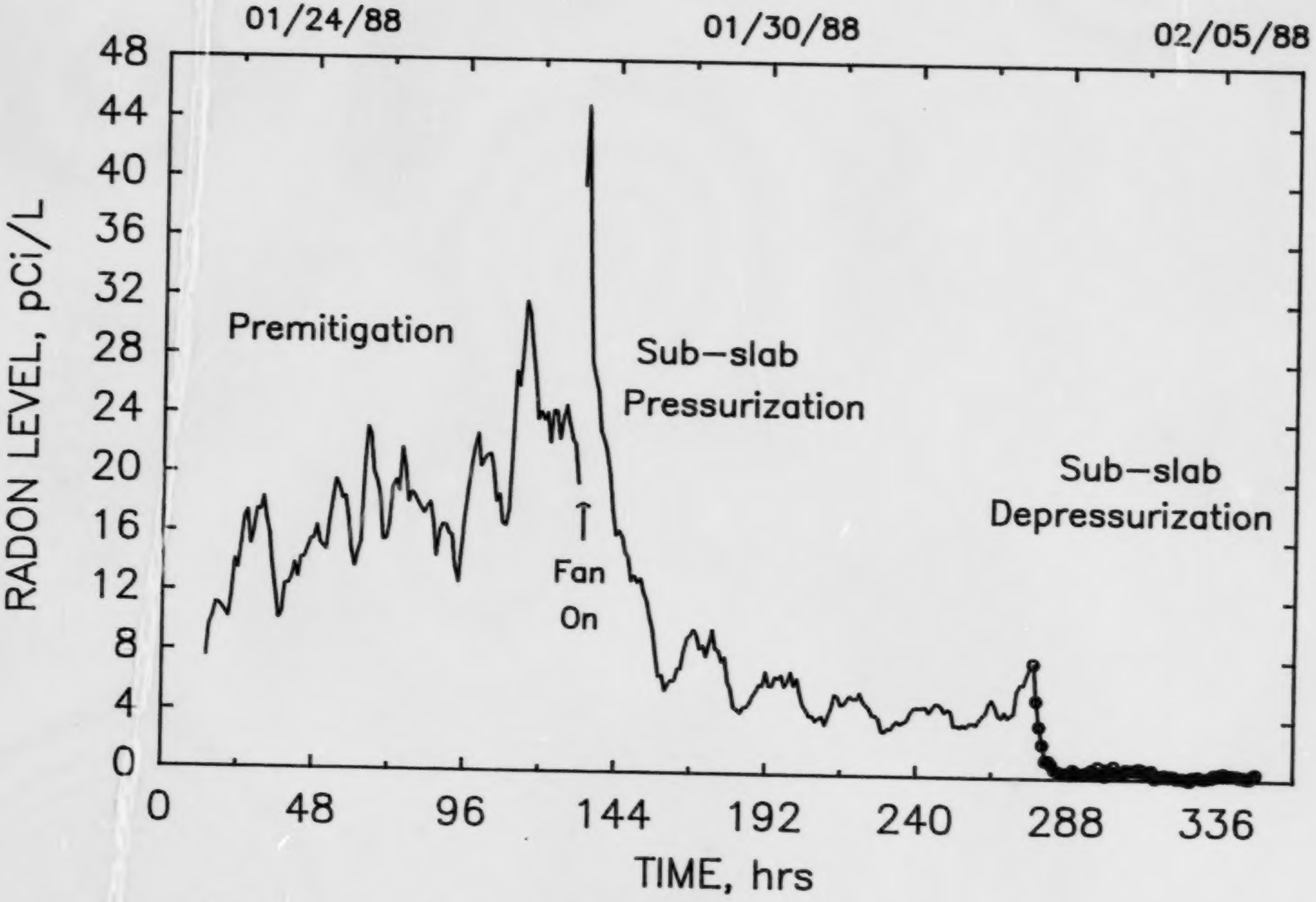


Figure 40. House DW41 continuous radon levels in basement den.

underneath the front entrance (front porch), installing vents in the walls of that entrance structure, constructing a treated barrier wall between the sub-entrance area and the area underneath the foyer, and installation of a sub-slab ventilation system under the foyer using an inline fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) with the exhaust routed through the barrier wall and out through the side wall of the front porch.

Phase 1 (SSP) Evaluation--

The sub-slab pressurization system was turned on at 1205 hrs on 1/27/88 with the fan blowing outside air under the slab. The system was operated in this mode from 1/27/88 until 2/2/88. Throughout this period the CRM located in the basement den was used to follow the radon levels. Within 2 hours following the turn-on of the pressurization fan, the radon levels in the basement den increased from about 19 pCi/L to 45 pCi/L. This drastic increase is thought to be due to the existing buildup of radon gas in the sub-slab region. Some of this high radon concentration soil gas is forced into the basement by the SSP system. In the next 8 hours the levels recovered to approximately 19 pCi/L. Which suggests that the continued introduction of outside air under the slab dilutes the radon concentration and also, perhaps does form a pressure barrier that prevents soil gas from accumulating under the slab. Within 24 hours the levels in the den were down to about 5 pCi/L. For the next 5 days the levels in the basement den were 5.4/3.0/9.7/1.7 pCi/L (ave/min/max/std.dev). These values represent a reduction of the radon levels by approximately 70 percent compared to pre-mitigation levels.

While the sub-slab area was being pressurized, investigations with a smoke bottle confirmed the fact that air was coming out from under the baseboards into the basement. Also, the homeowner noticed an increased feeling of cold and dampness ("clamminess") in the house and a strong odor of concrete dust. Analysis of the air in the same two basement rooms as before, showed that the Aldrin levels had increased by factors of about 5 to 9 times the pre-mitigation levels, or to 1.4 and 1.03 $\mu g/m^3$ in the same two rooms respectively. It was evident that the pressurization system was injecting cold outside air under the slab where it picked up moisture and concrete dust and transported these and traces of the termaticide into the basement area. While the radon levels decreased significantly, the effects of the air coming into the house could lead to moisture problems in the home as well as physical discomfort. Thus, for this house, the sub-slab pressurization technique was not a desirable alternative.

Phase 2 (SSD) Evaluation--

On 2/2/88 the Phase 2 (SSD-W) mitigation technique was instituted by reversing the fan to produce depressurization under the slab. Investigations with smoke confirmed that some house air was being drawn under the baseboards. The results of the CRM located in the basement den over the period 2/2/88 to 2/5/88 showed that the radon levels during the depressurization mode were 0.4/0.0/0.9/0.2 pCi/L (ave/min/max/std.dev). CC measurements over the period 2/5/88 to 2/8/88 gave radon levels in the basement of 1.3 and 1.4 pCi/L and levels upstairs of 1.1 and 1.0 pCi/L.

After the SSD system had been in operation for approximately 10 weeks, the gas sampling for termiticide was repeated in the same two rooms in the basement as before. These tests were carried on 4/12/88 and the results showed aldrin (and dieldrin) levels of less than 0.066 $\mu g/m^3$. These results suggest that the sub-slab depressurization system was effective in preventing the termiticide from entering the basement.

Thus, the single-point, sub-slab depressurization technique appears to be quite successful in controlling the radon levels in this house. No further action is anticipated for this house. Long-term alpha track detectors were installed on 2/9/88 and will be replaced quarterly for the next 2 years.

SECTION 7

DISCUSSION OF RESULTS

One of the objectives of this research project was to develop cost-effective techniques for radon mitigation in crawl space, basement, and combination houses in the Southeastern regions of the U.S. In order to accomplish this task, the houses in this study were not simply mitigated but were used as vehicles to test concepts of the mitigation process. While the same tests were not carried out at each individual house, the results can be grouped by house geometry for comparison and discussion purposes.

CRAWL SPACE HOUSES

Six mitigation techniques were evaluated in the nine crawl space houses as shown in the mitigation matrix of TABLE 10. With the exception of the IPCS (isolate and pressurize the crawl space) and the IDCS (isolate and depressurize the crawl space) methods, all the techniques were applied to two or more houses. The resulting evaluation of these techniques based on CRM data is listed in TABLE 14., and based on CC measurements (pre- and post-mitigation) is shown in TABLE 15.

TABLE 14. PERCENT RADON REDUCTION FOR EACH CRAWL SPACE MITIGATION SCHEME (BASED ON CONTINUOUS MONITOR DATA IN LIVING AREA)

	House ID Code								
Mitigation Technique	DW03	DW27	DW29	DW31	DW60	DW66	DW82	DW84	DW90
Isolate Crawl Space (ICS)			3			-15			
Isolate Vent C/S (IVCS)	18				27		-60		75
Isolate Dep. C/S (IDCS)							90		
Isolate Pres. C/S (IPCS)									
Sub-Poly Dep. (SPD)1 Point	69	60	64		77	72			92
(SPD)2 Point		87	84						
Sub-Soil Dep. (SSoP)2 Pts				61				58+	
(SSoP)4 Pts				84				86++	

Notes: Negative values indicate increased radon levels
+ Worst case condition
++ House open during part of test

TABLE 15. NASHVILLE RADON REDUCTION SUMMARY
(BASED ON CHARCOAL CANISTER MEASUREMENTS IN pCi/L)

House	Crawl Space			Basement			1st Floor			
ID #	Pre	Post	%Red	Pre	Post	%Red	Pre	Post	%Red	Notes
DW 03	21.9						7.1	2.6	64	1,10
DW 27	46.1	9.2	80				32.9	5.3	84	2
DW 29	27.2	5.7	79				16.1	7.0	56	1
		2.8	90					3.0	82	3
DW 31	29.9	2.0	93				26.0	2.2	92	4
DW 60	55.1	23.3	58				27.9	15.2	45	1
DW 66	26.0	7.6	71				12.1	2.8	77	1
DW 82	29.8	61.7	-107				14.9	0.7	96	5
DW 84	9.6						1.9			4,11
DW 90	29.7	7.1	76				15.8	2.4	85	1
DW 43				59.2	4.8	92	23.1	1.4	94	6
DW 58				56.8			23.9			12
DW 78				41.4	2.8	93	19.8	1.5	92	6,13
DW 12				11.1	4.4	61	7.8	4.8	39	8
DW 14				88.3	11.3	87	47.6	3.8	92	9,14
					3.0	97				9,15
DW 41				19.3	1.4	93	13.4	1.0	93	7

Notes: (See TABLE 10 for mitigation codes)
Negative values indicate increased radon levels
1. ICS+SPD
2. Two Point SPD
3. ICS+Two Point SPD
4. Four Pit SSoD
5. IDCS
6. Two Point SSBWD
7. SSD-W
8. Two Point SSD-W
9. Two Point SSBWD+SSSPD
10. No measurements in crawl space
11. No Post-Mitigation CC measurements
12. House not mitigated
13. No duplicate done upstairs
14. Basement readings on top of crawl space wall
15. Basement readings 4' from floor 6' from C/S wall

ICS - Isolation of Crawl Space

The technique of isolating the living areas from the crawl space and thereby stopping or greatly reducing the radon entry was tried on houses DW29 and DW66. In theory the method seemed simple and straightforward. In practice the method was difficult to apply. In the Nashville houses the sub-flooring was typically 1 in. by 6 in. boards laid diagonally to the floor joists. Air movement, from the crawl space up into the cracks between these boards, could be demonstrated at every location. The air flow was much greater near the points at which the HAC cold air return plenum was constructed between the floor joists. Sealing the cracks between the sub-flooring boards was difficult and achieved only limited success, even in those houses that had no insulation in the floor. In those houses with insulation, it was more time consuming (and more costly) and even less successful. Attempts to seal the floor using a variety of spray foams, and plastic liners applied to or attached to the floor joists were ruled out as too expensive and therefore not cost-effective for this study. The floor openings that were routinely sealed in these houses were the utility penetrations (electrical wiring, water and gas pipe entries, and waste pipe penetrations for drains and under the bath tub openings) and the larger openings in the box joists used for air return plenums.

In the two Nashville houses (DW29 and DW66) where this ICS technique was applied, the results of sealing alone were not impressive. In DW29 the radon reduction was only about 3% and in DW66 the levels actually increased by approximately 15%. These reductions were based upon CRM measurements in the living space of the houses as shown in TABLE 14. No CC measurements were carried out for this technique.

Thus it appeared that attempts at isolating the crawl space from the living areas are a questionable means of reducing the indoor radon levels when used as the only mitigation technique.

IVCS - Isolation and ventilation of crawl space

This technique of isolating the crawl space and opening the existing foundation vents was tried on four of the houses: DW03, DW60, DW82, and DW90. The radon reductions ranged from -60% (an increase) for DW82, to 75% (decrease) for DW90 as shown in TABLE 14. No CC measurements were carried out for the IVCS technique.

In the worst case, DW82, the garage had been converted to a den and was open to the rest of the living areas. In building the den, the floor was constructed using typical wood floor joist techniques. Unfortunately, the floor joists were so close to the old garage slab that access to this area was impossible. The number of entry points into the den was unknown. For the remainder of the house, the overhead floor was readily accessible from the crawl space. In this area all the major openings (those greater then a quarter inch) and many of the minor cracks and openings were closed. However, the radon levels in the living area increased, as seen in Figure 33 above.

The causes for this increased infiltration of radon into the living area was not determined. It was speculated that the closure of all but two or three of the block vents reduced the amount of ventilation area, and thus did not allow sufficient air to flow through the crawl space to dilute and exhaust the radon gas. This, combined with the fact that complete sealing of the openings from crawl space to living area were impossible, could have lead to a situation in which the house stack effect pulled in more radon gas than it would have if more of the vents were open. This was supported by data from the houses DW03, DW60, and DW82 (Figures 27, 31, and 33), which indicate that the diurnal variations increase significantly during the passive ventilation testing periods. In general, the block vents in the majority of the houses were very close to ground level, which was also the region of least air movement. Additionally, the vents were typically screened (deliberately by the homeowner) by vines, shrubs, or flowers which tended to block air movement through the vents.

In summary, for the applications here, it appeared that isolation and passive ventilation of the crawl space alone would not likely reduce the levels of upstairs radon below the 4 pCi/L level unless the leakage area between house and crawl was or could have been reduced to very low values and the ventilation area of the crawl space increased.

IDCS - Isolation and Depressurization of the Crawl Space

Although three houses were scheduled for mitigation by the technique of isolation and depressurization of the crawl space, only one house (DW82) actually had the system implemented. The reduction achieved was rather dramatic as seen in Figure 33. Based on the CRM data, the levels in the den were reduced by 90%, and from the pre- and post-mitigation CC measurements the reduction was 96%; however, the levels in the crawl space increased. The levels here went up from 29.8 pCi/L to 61.7 pCi/L, an increase of 107%. While this posed no problem for this house, it could lead to problems in others. If there were HAC ducts in the crawl space, the increased radon levels could leak into the return ducting and be distributed throughout the house. Also, since the openings between the living area and the crawl space can never be entirely closed, there could be fairly large amounts of conditioned air drawn into the crawl space, resulting in a substantial energy penalty for the homeowner. In house DW82 it was found that the foundation walls had sufficient leakage areas that the major portion of the air flow into the crawl was from outside the house. Thus no substantial energy penalty was expected.

IPCS - Isolation and Pressurization of the Crawl Space

The technique of isolation and pressurization of the crawl space was originally scheduled to be tried as a Phase I mitigation on house DW82. However, at the time of installation, there were several uncertainties as to the correct method of installing the available device (Current Indoor Air Systems, Inc., Boulder, CO, model 300). Consequently, installation of the IPCS technique was cancelled for this house. The device was later installed in another crawl space house, DW60, but no data as to its operation or effectiveness is available at the time of this report.

SSoD - Sub-Soil Depressurization

The technique of depressurizing the soil directly was implemented on two houses, DW31 and DW84. The soil in the crawl space of DW31 was fairly loose and permeable to air movement as was measured during the diagnostic visits in October 1987. The soil under house DW84 was quite different. The surface of this soil was very hard and had large desiccation cracks up to a half inch wide throughout. The systems installed in each of these houses was basically identical. Four, evenly spaced, suction pits approximately 24 in. wide and about 12 in. to 18 in. deep were dug in the soil and connected to a single fan (model K6, R.B. Kanalflakt, Inc., Sarasota, FL) exhausting to the outside. The area of the crawl space under DW31 was approximately 780 ft^2 and under DW84 was approximately 1360 ft^2. Thus the number of suction points per square foot of soil was one per 195 ft^2 for DW31 and one per 340 ft^2 for DW84.

The pressure field extension in the soil was measured by carefully drilling a series of 3/8 in. diameter holes into the soil. These holes were generally 12 in. to 18 in. deep, although in some instances the soil was sufficiently loose that it tended to slide into the bottom of the hole. In those cases it was difficult to estimate the depth of the test hole. The test holes were located at varying distances from a suction pit as shown in Figures 7 and 13. In carrying out the measurements, a 12 in. length of 1/8 in. diameter steel tubing was carefully inserted into the hole. The top of the hole was sealed as tightly as possible by means of a rubber stopper at the top of the tube. The steel tube was connected to an electronic manometer (Neotronics, Gainesville, GA, model EDM-I) with a sensitivity of 0.001 inches of water. The results of these measurements at each of the houses are summarized in TABLES 16 and 17 and shown graphically in Figures 41 and 42.

TABLE 16. SOIL ΔP MEASUREMENTS AT HOUSE DW31

Distance from Suction Point A (ft)	All Readings In Inches Of Water			
	Leg A to D (2 Pts)	Diagonal A to B (2 Pts)	Leg A to D (4 Pts)	Diagonal A to B (4 Pts)
0	-1.48	-1.48	-0.921	-0.921
2	-0.03	-0.071	-0.145	-0.063
6	-0.001	-0.013	-0.007	-0.005
12	0	-0.011	-0.109	-0.005
		Fan Flowrate		
Q(cfm)	22	22	41.4	41.4

TABLE 17. SOIL ΔP MEASUREMENTS AT HOUSE DW84

Distance from Suction Point (ft)	All Readings In Inches Of Water Leg B to D (2 Pts)	Diagonal A to B (2 Pts)	Leg B to D (4 Pts)	Diagonal A to B (4 Pts)	Leg C to B (4 Pts)
0	-1.344	-1.416	-0.923	-0.933	-0.925
2	-0.004	-0.342	-0.001	-0.220	-0.001
6	-0.002	-0.002	-0.003	-0.004	-0.005
12	-0.001	0	-0.002	-0.001	0
		Fan Flowrate			
Q(cfm)	43.5	43.5	87.3	87.3	87.3

In TABLE 16 the references to "Leg" and "Diagonal" refer to the location of the measurement points in the soil. Points along the leg A to D, for example, were located along the line between suction pits A and D (see Figure 7) and the distances were measured from pit A. Points along the diagonal A to B were measured from pit A and lay along the line between pit A and pit B of the four pit grid. Measurements made with only two pits active were carried out with only pits A and B connected to the fan. The locations of both the suction pits and the test points are shown in Figure 7. The locations of the test points in TABLE 17 are denoted similarly and are shown in Figure 13. Here, the reference to "Leg B to D" and "Leg C to B" imply that the distances were measured from pits B and C respectively.

As seen in TABLES 16 and 17, the depressurization in the soil could reliably be measured at distances of up to 6 ft from the suction pit, and in several cases up to 12 ft. In Figures 41 and 42, the pressure readings at each test point have been normalized to a pit pressure of -1.00 in. of water in order to compare the various measurements. For House DW31, the pressure field dropped to about 10% of the pit pressures within 2 ft and around 1% at distances of about 6 ft. In the soil under House DW84, the pressure decrease was even more drastic. Here, the pressure dropped to approximately 1% of the pit pressure within 2 ft, although some pressures were measured as far out as 6 ft.

These results were consistent with the observed nature of the soils under the two houses. The soil under DW31 was moderately loose and should have had a higher permeability than the soil under DW84, which was hard packed clay. Thus, each suction point of the system was capable of producing a measurable soil depressurization over an area of at least 113 ft^2 and perhaps as large as 452 ft^2.

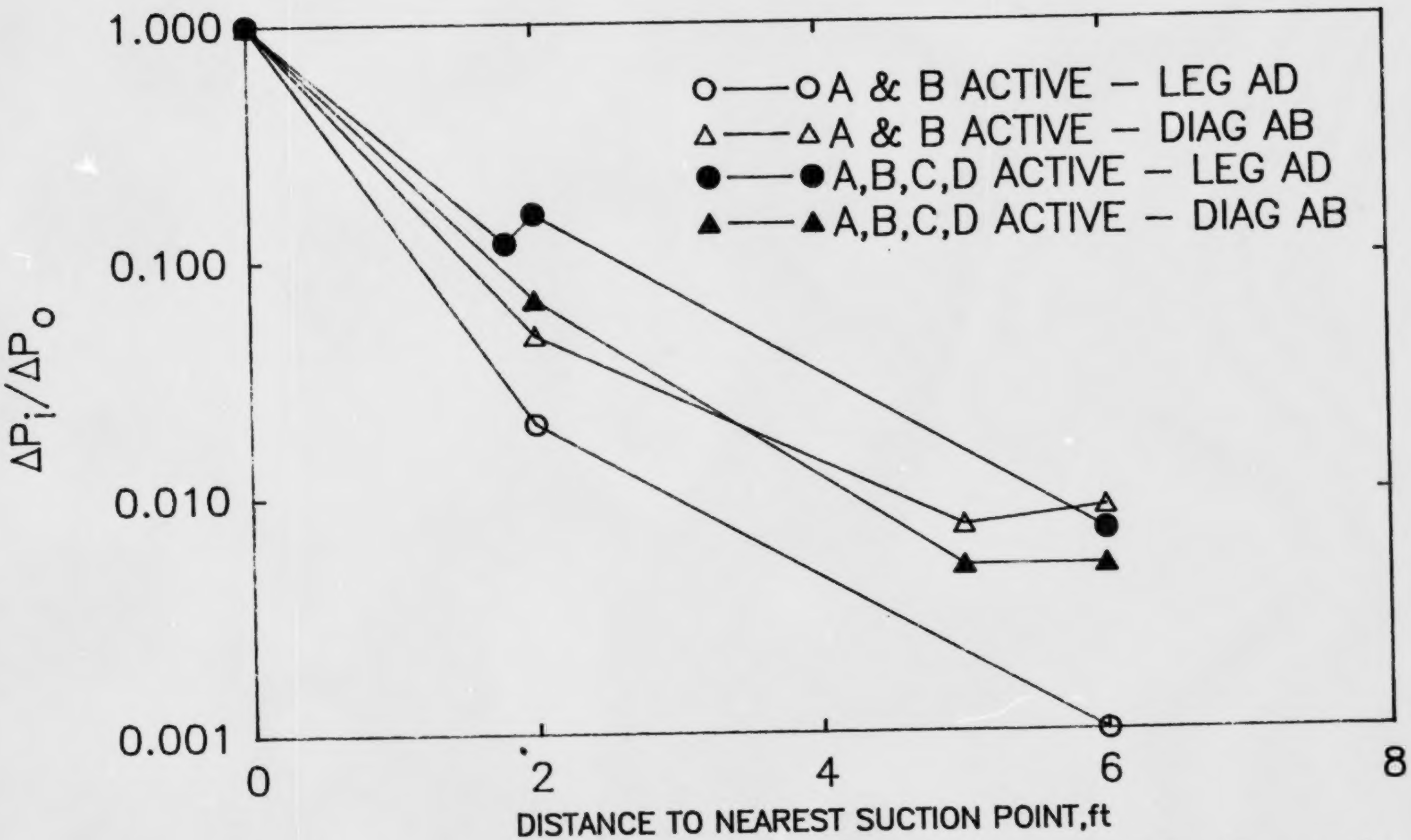


Figure 41. Depressurization in soil of SSoD system at House DW 31.

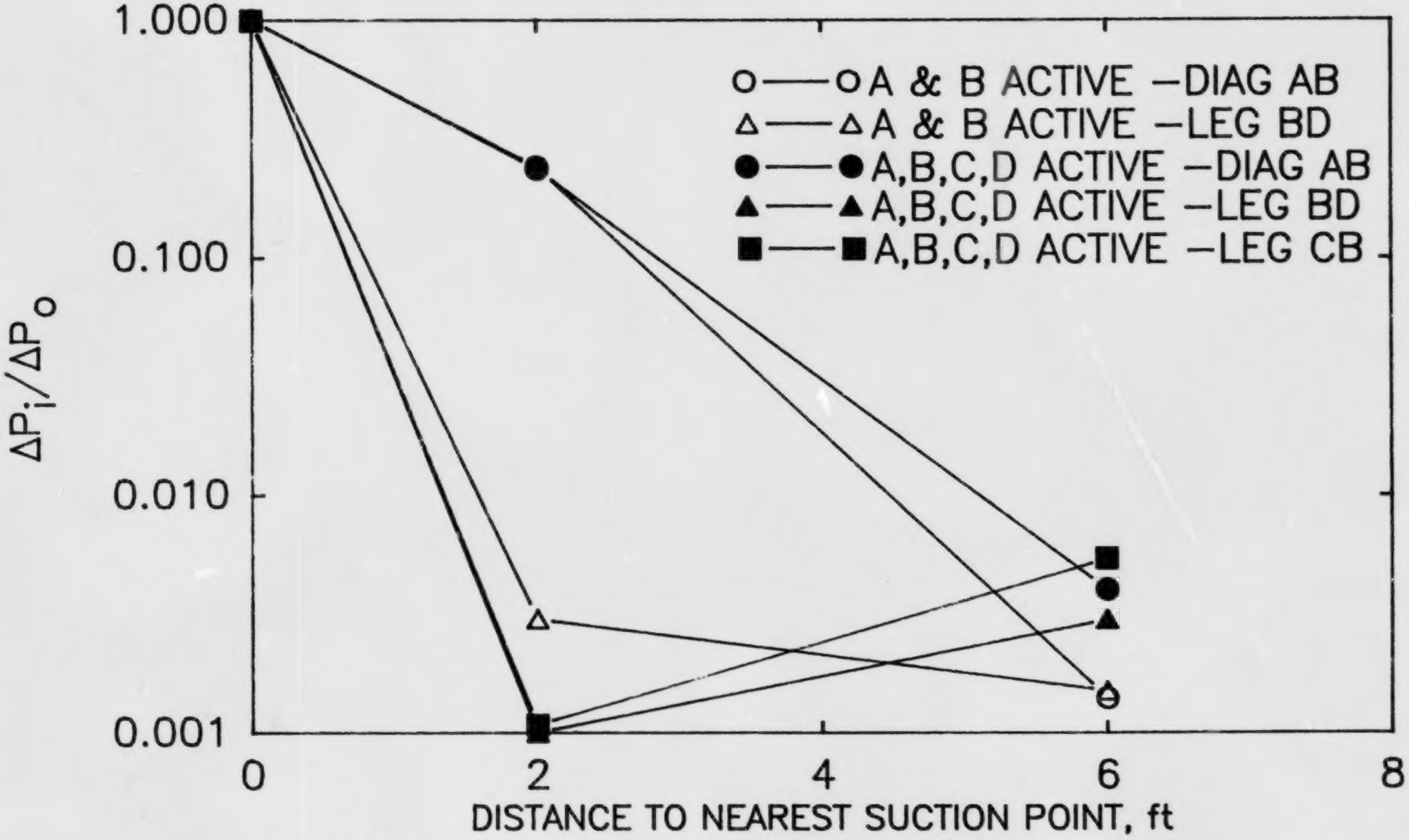


Figure 42. Depressurization in soil of SSoD system at House DW84.

In terms of the reduction of the radon levels in the living space, the SSoD technique achieved reductions of approximately 85% as seen in TABLE 14 for the CRM measurements, and up to 92% based on the CC measurements as shown in TABLE 15. Unfortunately, the method has been applied to only two houses. If the technique is to be used on any large scale it should be tested for other types of soils and at different locations.

SPD - Sub-Poly Depressurization

The technique of depressurizing the soil under a plastic membrane had the widest application in the current group of houses. Six of the nine crawl space houses had an SPD system installed and evaluated. Based upon the CRM data, the SPD technique achieved reductions ranging from 60 to 92% (TABLE 14). Based on pre- and post-mitigation CC measurements (TABLE 15), the reductions range from 45 to 85%.

In only one house (DW27) was the poly sheeting sealed to both the walls and piers, and to itself at the overlaps. In some of the houses (DW03, DW29, DW60) the sheeting was sealed to the piers nearest the suction point. In the remainder of the houses, no attempt was made to seal the poly. Pressure measurements under the plastic sheeting were carried out in all but one house (DW27). The location of these test points are shown in the respective diagrams of the crawl spaces of the houses. The results of these measurements are summarized in TABLE 18 and in Figure 43. Measurements were made using an electronic micromanometer (Neotronics, Gainesville, GA, model EDM-I) with a sensitivity of 0.001 inches of water column. In Figure 43, the data have been normalized to a common suction point pressure of -1.00 in. of water to enable comparison between different houses. Because of this, the normalized readings could, in some cases, fall outside of the instrument sensitivity (for example, a reading of -0.001 in. water for a suction pressure of -1.5 in. water would be normalized to 0.0007). In each of these houses, measurable pressures

TABLE 18. PRESSURE MEASUREMENTS UNDER THE SHEETING OF SUB-POLY DEPRESSURIZATION SYSTEMS

Distance from Suction Point (ft)	Δp relative to crawl space(inches WC)						
	DW03	DW29 1 pt.	DW29 2 Pts. Pt. A	DW29 2 Pts. Pt. B	DW60	DW66	DW90
0	-1.551	-1.274	-0.958	-0.97	-1.024	-0.86	-1.045
2	-0.200	-0.062	-0.078	-0.034			
3					-0.379		
4						-0.071	-0.031
6	-0.003	-0.01	-0.011	-0.009	-0.066	-0.013	-0.015
12	-0.001	0	0	-0.001	-0.005	-0.005	0
Fan Flowrate Q(cfm)	37.0	87.3	104.8	104.8	N.A.	N.A.	N.A.

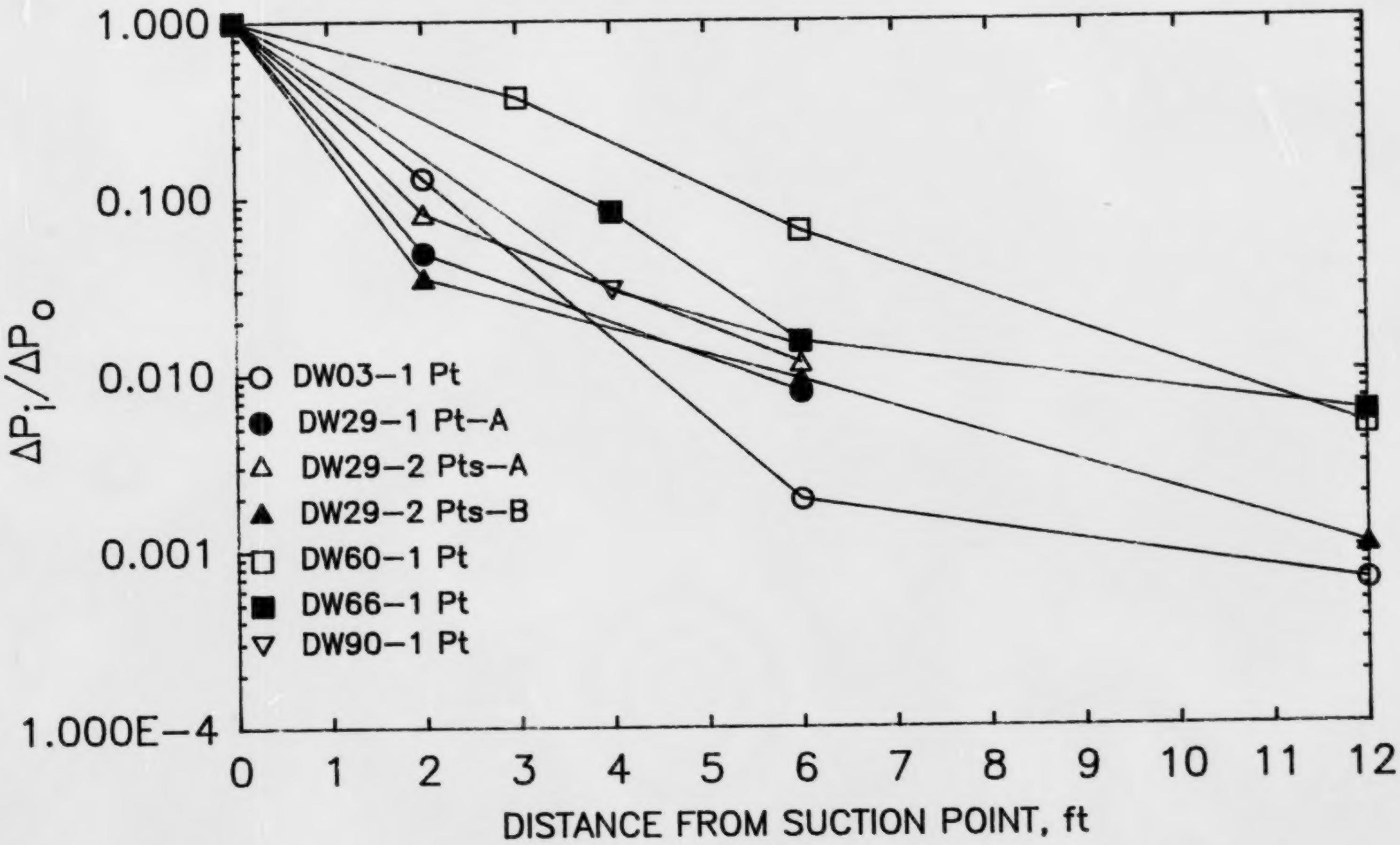


Figure 43. Depressurization under poly of SPD systems.

were detected at distances of up to 6 ft from the suction point, and in some cases up to 12 ft. At larger distances the pressures were not measurable with the manometer but, in most cases, air flow under the poly was observed using smoke as a tracer.

In two of the houses (DW27 and DW29), a second suction point was added to increase the extension of the depressurization under the poly. These two houses had the largest crawl space area of any of the houses. In both cases, the same fan was used for both suction points. None of these houses had any type of perforated pipe or ducting network installed under the poly with one exception. In one location (DW27), drainage material (Enkadrain Type 9010, BASF Corp., Fibers Div., Enka, NC) was placed under the sheeting to improve air flow. In general, this is necessary only where the soil surface is excessively hard and smooth or the crawl space area is exceptionally large, as in the case of DW27.

In summary the SPD technique was the most widely used and appears to be the most applicable to crawl space houses in which the upstairs levels are in the 10 to 30 pCi/L range. There are questions regarding the technique that have not been fully answered in this study. In the SPD installations, the material used for the houses in this study was standard, builder-grade, 6 mil polyethylene sheeting. The properties of this material (thickness, puncture resistance, permeability, and resistance to ultraviolet light and temperature degradation) vary from location to location in a single sheet and perhaps from source to source. Also, the tear and puncture resistance are not believed to be sufficiently high to withstand normal traffic (such as by service personnel from the utility companies, the termite control organizations, or by the homeowner) that might be expected in a crawl space. Other materials such as cross-laminated high-density polyethylene films or lagoon liners need to be examined for use in these applications. Other questions that have not been addressed include the amount of energy penalty resulting from the SPD system withdrawing house air down into the crawl space, and the effects of the system upon the house frame as a result of moisture removal from the crawl space.

BASEMENT, SLAB-ON-GRADE, AND COMBINATION HOUSES

One- or two-point, sub-slab depressurization (SSD) systems were installed in five of the six houses with basements (DW43, DW78, DW12, DW14, and DW41). The remaining basement/crawl space house (DW58) was not mitigated during this reporting period. In two of these houses (DW43 and DW78) the effects of suction pit shape were evaluated, and in two different houses (DW12 and DW14) the effects of suction pit size were investigated. In the remaining house (DW41) the suction pit was a single size (wide). This house (DW41) did not lend itself to extensive sub-slab pressure field measurements. In some of the houses, additional mitigation measures were implemented such as, sub-poly depressurization, block-wall depressurization, and sealing of the block-wall face. The results of each mitigation technique were not always unambiguous and easily discerned from those of other mitigation steps. However, to the extent that the effects of each mitigation method upon the radon levels in the house could be isolated, the results will be described in the following paragraphs.

The radon reductions achieved for these houses ranged from 28 to 98%, as shown by the CRM data in TABLE 19. The final radon levels, as measured with the CC detectors, are shown in TABLE 15 above. The house with the greatest reduction (DW41), had a single suction point installed near the edge of the slab, under the front foyer. The excellent sub-slab communication allowed the sub-slab area to be ventilated from a single point. Also, the area of exposed soil located under the front porch was small (less than 100 ft^2) and was easily isolated from the living areas by construction of a treated plywood barrier wall with a sealed access door.

TABLE 19. PERCENT RADON REDUCTION FOR EACH
BASEMENT TYPE MITIGATION SCHEME
(BASED ON CONTINUOUS MONITOR DATA IN BASEMENT)

	House ID Code					
Mitigation Technique	DW43	DW58	DW78	DW12	DW14	DW41
Sub-Slab Pressurization (SSP)						70^
Sub-Slab Depressurization (SSD)	28*		78	92	70	98*
SSD + Block Wall Depress.(BWD)	42-60				85	
SSD + BWD + Seal Exposed Soil			93		93**	
SSD + BWD + Seal Wall Face	92					

Notes: Unless specified otherwise, all SSD systems include two suction points
* Single Sub-slab Depressurization Point
^ Single Sub-slab Pressurization Point
** Top of Wall sealed

The lowest reduction show in TABLE 19, was also achieved using a single sub-slab suction point (DW43). However, in this house the communication under the slab was poor, so that an additional suction point was required. Also, this house had a cement capped perimeter shelf around most of the basement. This shelf was constructed of coarse cinder blocks which allowed radon gas to enter the basement through their face openings. Incorporating block wall suction achieved a reduction in the range of 42 to 60%. Because of the high porosity of the block comprising the wall, acceptable reductions were not achieved until the wall was coated with a sealer (SurWall Brand). The final reduction for house DW43 was 92% as measured by the CRM in the basement. Post-mitigation CC measurements gave basement and first floor reductions of 92% and 94% respectively as shown in TABLE 15.

For house DW12 the exposed soil was contained behind an 18 inch thick cut stone wall. This area was covered with 6 mil polyethylene sheeting but no depressurization under the sheeting was implemented. Final reduction for this house was 92% as measured with the CRM. Subsequent CC measurements indicated that the reduction in the basement was 61% and 39% upstairs. It appeared that there was still an uncontrolled radon entry path into the house. This path was most likely from the soil in the crawl space. A suction point may have to be installed under the poly covering the soil. This will be determined following additional long-term monitoring with ATDs.

The exposed soil in house DW14 was located behind a concrete block wall. This area was covered with 6 mil poly sealed to the surrounding walls. Depressurization under the poly was accomplished by breaking through the adjoining wall (and under the poly) with the sub-slab system. The open block tops of the wall were filled with expanding closed-cell foam. This combination achieved a reduction of 85%. After the top of the wall was covered with a treated 2"x12" board sealed to the top of the blocks with urethane sealant a final reduction of 93% was achieved in the basement as measured with the CRM (TABLE 19). Subsequent CC measurements gave reductions of 97% in the basement and 92% in the den upstairs.

The remaining basement/combination house (DW78) had a two-point sub-slab suction system installed and achieved a radon reduction of 78%. The area of exposed soil in this house (600 ft^2) was roughly twice the area of the slab (300 ft^2) and consequently represented a major source for radon entry into the basement. The soil was covered with 6 mil poly sealed to the slab perimeter wall. The open block tops of the interior wall were sealed with closed-cell expanding foam, and the SSD system was extended into the wall and thus under the poly covering the soil. The final reduction in the radon levels was 93% as measured in the basement with the CRM. CC measurements gave similar results of 93% reduction in the basement and 92% upstairs.

The only house in which the sub-slab pressurization (SSP) technique was implemented was DW41. Here the fan was initially installed to force outside air under the slab. The reduction achieved (70%) was surprisingly high in view of the fact that a polystyrene foam beadboard was located at the edge of the slab. This allowed sub-slab air to enter the basement interior via the finished walls and baseboards. This entry was verified by use of a smoke bottle and was confirmed by the homeowner as an increase in humidity and odor in the basement. Concurrently, measurements of the levels of termaticide (aldrin) in two rooms of the basement indicated an increased from pre-mitigation concentrations of 0.3 and 0.12 $\mu g/m^3$ to levels of 1.40 and 1.03 $\mu g/m^3$ with pressurization under the slab. Subsequent measurements in these two rooms, after the system was run in the sub-slab depressurization mode for approximately 10 weeks, showed the levels of aldrin (and dieldrin) to be less than 0.066 $\mu g/m^3$. Thus, while SSP could be effective in lowering the radon levels, it could also lead to other problems for the homeowner.

SSD-W/N - Sub-slab Depressurization with Wide/Narrow Suction Pits

The first house in which the effects of suction pit shape on pressure field extension were investigated was DW43. The results of these tests, along with measurements taken with both suction pits installed, are summarized in

TABLE 20. In conducting the measurements of the effects of pit shape, only suction pit A was used. The location and identification of the pit and test points are shown in Figure 15 above. With the narrow pit under the slab and -1.73 in. of water pressure at suction hole A, the only test point with measurable depressurization was Fa, located about 8 ft from A. At other test points no pressure could be measured. However, at several locations, smoke was observed to move slowly down into the test hole. The suction pit was then modified to a wide pit (28in. W x 10in. D). The 4in. diameter extension in the bottom of the wide pit was plugged with closed-cell, expanding foam and the pressure field remeasured. Details of the pit shapes and sizes are shown in Figure 16 above.

TABLE 20. EFFECTS OF SUCTION PIT SHAPE ON SUB-SLAB PRESSURE FIELD EXTENSION AT HOUSE DW43

			Δp Relative to Basement (in.water)		
Test Point No.	Distance To Suction Point A (ft)	Distance To Suction Point B (ft)	Suction Point A Active	Suction Point B Active	Suction Point A&B Active
Narrow Suction Hole (4in.x 30in.)					
A	0.00	25.75	-1.730	N.A.	N.A.
Fa	7.75	18.00	-0.001	N.A.	N.A.
Fb	16.75	12.42	0.000	N.A.	N.A.
Fe	17.42	15.17	0.000	N.A.	N.A.
Ff	19.42	14.50	0.000	N.A.	N.A.
Fc	19.58	6.50	0.000	N.A.	N.A.
Fd	23.67	2.00	0.000	N.A.	N.A.
B	25.75	0.00	0.000	N.A.	N.A.
Wide Suction Hole (28in.x 10in.)					
A	0.00	25.75	-1.430	0.000	-1.330
Fa	7.75	18.00	-0.050	-0.003	-0.046
Fb	16.75	12.42	-0.005	-0.005	-0.009
Fe	17.42	15.17	-0.005	-0.005	-0.016
Ff	19.42	14.50	0.000	0.000	0.000
Fc	19.58	6.50	-0.008	-0.020	-0.028
Fd	23.67	2.00	0.000	-0.094	-0.108
B	25.75	0.00	-0.002	-1.210	-1.190

The results are shown in TABLE 20 along with the results of pressure measurements made, with pit B active, and with both pits A and B active. With a wide suction pit the extension of the pressure field was dramatic. With the exception of isolated test points (Fd and Ff), the depressurization under the slab was measurable at distances of better than 25 ft from the suction hole. The sub-slab depressurization field values are shown in Figure 44, plotted as a function of the distance from the suction point. In this figure, the pressure values measured at each test point have been divided by the pressure at the suction point (i.e. normalized to -1.0 in. of water).

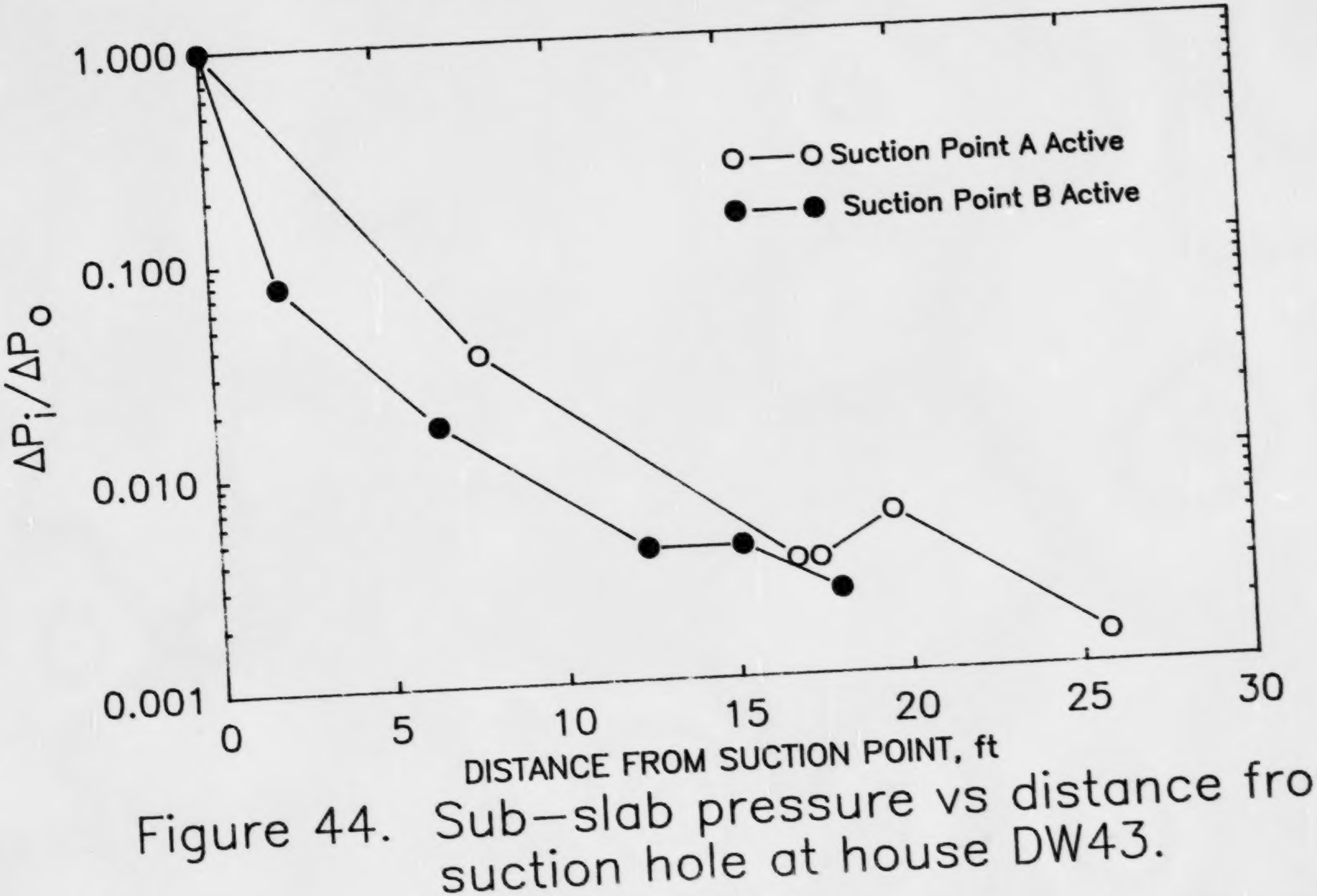


Figure 44. Sub–slab pressure vs distance from suction hole at house DW43.

The values shown in TABLE 20, for the wide suction pit, remained relatively unchanged when the plug was removed from the extended hole in the bottom of the wide pit. Any differences observed with this combined configuration were well within the statistical variation of the measurements. In summary, for House DW43, the narrow, deep suction pit had very little effect upon the sub-slab pressures. Measurements of the pressure field extension under the slab showed the wide-shallow pit to be more effective than the narrow-deep pit.

The second house in which the effects of the suction pit shape were investigated was DW78. Here, two suction points were installed at diagonal corners of the basement slab as shown in Figure 21. Initially, the suction holes under the slab were 4 inches wide and 30 inches deep. Following measurements with this shape, the suction pits were enlarged to 28 inches wide and 10 inches deep. The narrow hole extensions in the bottom of the wide pits were filled with closed-cell foam before testing the pressure field extensions of the wide pits. Finally, the foam plugs were removed and testing continued with the combination suction pit. Details of the suction pit shape and size are shown in Figure 16 above.

The results of the measurements of sub-slab pressures are tabulated in TABLE 21 and shown graphically in Figure 45. Measurements were made at a single test point located 12 ft from pit A and 10 ft from pit B. For each pit shape, the pressures at both the suction hole and the test hole were monitored with a micromanometer (Neotronics, Gainesville, GA, model EDM-I). In Figure 45, the pressure values measured at the test point have been divided by the corresponding values measured at the suction points, to allow comparison between the various pit shapes and suction holes.

TABLE 21. EFFECTS OF SUCTION PIT SHAPE ON SUB-SLAB PRESSURE FIELD EXTENSION AT HOUSE DW78

Pit No.	Hole Size in.(wxd)	Hole Volume (ft^3)	Hole Area (ft^3)	Source Δp_o (in.WC)	Test Δp_i (in.WC)	Distance to Source (ft)	$\Delta p_i/\Delta p_o$	Flow Rate (cfm)
A	4x30	0.218	2.705	-1.33	-0.042	12	0.032	37.5
A	28x10	3.563	10.297	-1.16	-0.056	12	0.048	48.0
A	28x10+4x20	3.708	12.129	-0.99	-0.050	12	0.050	45.4
B	4x30	0.218	2.705	-1.53	-0.032	10	0.021	27.0
B	28x10	3.563	10.297	-1.08	-0.036	10	0.033	30.5
B	28x10+4x20	3.708	12.129	-0.94	-0.036	10	0.038	34.9
A+B	2*(4x30)	0.436	5.410	-1.24	-0.079	11	0.0637	64.5
A+B	2*(28x10)	7.126	20.594	-1.00	-0.095	11	0.0945	78.6
A+B	2*(28x10+4x20)	7.416	24.258	-0.90	-0.093	11	0.1033	76.8

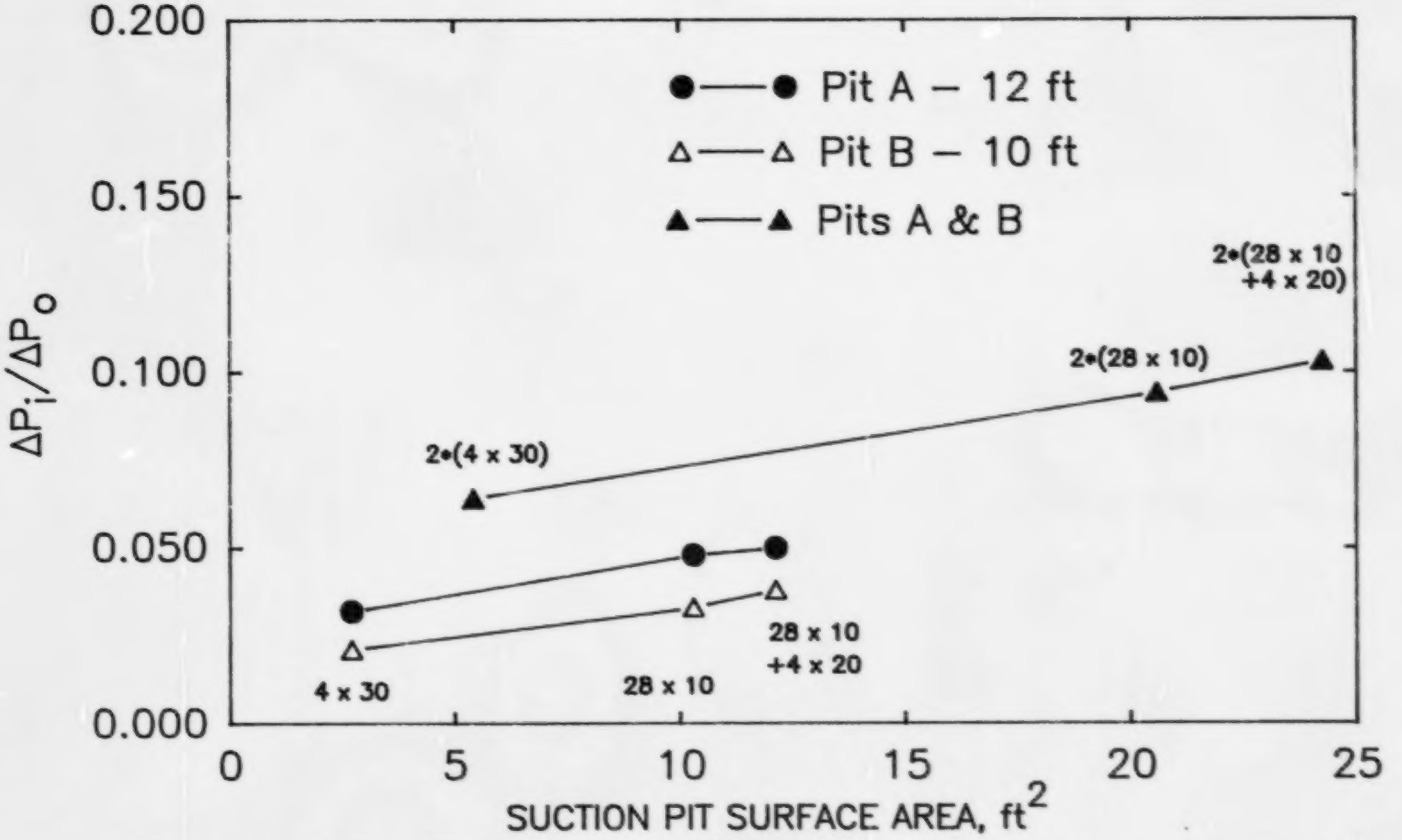


Figure 45. Relative sub–slab pressures vs suction shape, measured at house DW78.

The effects of changing from a narrow-deep pit to a wide-shallow pit were not so dramatic as that found at house DW43. For suction pit A, the relative Δp at the test point increased by about 50% when the wide hole was installed. For suction pit B, this increase was approximately 57%. When the 4x20 hole extension was added to the wide pits the Δp values increased by only about 4% for pit A and 15% for pit B. These results imply, but do no conclusively prove, that the width of the pit was more important than the depth in improving or producing a pressure field under the slab. However, this conclusion was corroborated by the measurements taken at houses DW14 and DW12. These results will be discussed in the following paragraphs.

SSD-P - Sub-slab Depressurization with Progressive Pit Size

In houses DW12 and DW14, the suction pits under the slab were installed and progressively increased in size as the pressure field under the slab was monitored. The design details and sizes of the suction pits were described in Figure 23 above. In some locations, it was impossible to achieve the exact pit dimensions shown in this figure.

The results of these measurements are shown in TABLE 22 for house DW12, and in TABLE 23 for house DW14. In TABLE 22, the data for suction pit A shows that this point had very poor communication with most areas under the slab. While digging this pit, rock was encountered at a depth of 8 inches. The stone appeared to be part of a large limestone layer of unknown thickness. Efforts to break through this stone were unsuccessful. The soil under pit B was a mixture of clay and small stone. No bedrock was encountered under this pit. The data for pit B are plotted in Figure 46. In this plot, the pressures measured at each test point have been divided by the pressure at the suction point before plotting. The data show a family of pressure values for each test point, or distance from the suction hole. As the surface area of the suction hole increased, the pressures at the test holes increased, up to a limit. Increases in the suction hole surface beyond about 6-8 ft^2 resulted in very little improvement in the sub-slab pressure field. The solid lines in Figure 46 are second order regression lines for each test point data set. The data at test points Fb and Fd were inverted to what one might have expected. This was likely due to discontinuities under the slab.

The data for house DW14 (TABLE 23) illustrates that the communication under the slab was not as good as that at DW12. During excavation of the pits, the soil at hole A was hard-packed clay with no stones or gravel. The soil under point B was loose black loam with natural stones of assorted diameters. This latter point was located on the down-hill side of the basement which apparently was constructed over fill material. The depth of this fill material was not determined.

TABLE 22. SUB-SLAB PRESSURE FIELD EXTENSION FOR VARIOUS PIT SIZES
(DATA TAKEN AT HOUSE DW12)

					Test Point Fa		Test Point Fb		Test Point Fc		Test Point Fd	
Pit No.	Hole Size ("wx"d)	Hole Volume (ft^3)	Hole Area (ft^2)	Source Δp_0 (in.WC)	Δp_a (in.WC)	Distance to Source (ft)	Δp_b (in.WC)	Distance to Source (ft)	Δp_c (in.WC)	Distance to Source (ft)	Δp_d (in.WC)	Distance to Source (ft)
A	0	0	0.087	-1.76	0	9	0	14	0	35	-0.001	30
A	10x8	0.364	3.011	-1.76	0	9	-0.004	14	-0.002	35	-0.004	30
B	0	0	0.087	-1.7	0	34	0	38	0	10	0	11
B	10x12	0.545	3.884	-1.65	-0.038	34	0	38	-0.054	10	-0.011	11
B	20x16	2.909	9.163	-1.61	-0.061	34	-0.002	38	-0.064	10	-0.018	11
B	24x18	4.712	12.567	-1.61	-0.062	34	-0.002	38	-0.066	10	-0.02	11

TABLE 23. SUB-SLAB PRESSURE FIELD EXTENSION VS PIT SIZE
(DATA TAKEN AT HOUSE DW14)

					Test Point Fa		Test Point Fb		Test Point Fc		Test Point Fd	
Pit No.	Hole Size ("wx"d)	Hole Volume (ft^3)	Hole Area (ft^2)	Source Δp_0 (in.WC)	Δp_a (in.WC)	Distance to Source (ft)	Δp_b (in.WC)	Distance to Source (ft)	Δp_c (in.WC)	Distance to Source (ft)	Δp_d (in.WC)	Distance to Source (ft)
A	0	0	0.087	-1.74	0	7.5	0.001	55	0	16.5	0.001	53.5
A	10x12	0.545	3.884	-1.75	-0.019	7.5	0.001	55	0	16.5	0.001	53.5
A	20x16	2.909	9.163	-1.74	-0.019	7.5	0.005	55	0	16.5	0.003	53.5
A	24x18	4.712	12.567	-1.65	-0.073	7.5	0.004	55	-0.001	16.5	0.002	53.5
B	0	0	0.087	-1.67	-0.003	55	-0.005	8	0	47	0.0015	24
B	10x12	0.545	3.884	-1.48	-0.001	55	-0.028	8	0	47	0.001	24
B	20x16	2.909	9.163	-1.38	0.006	55	-0.049	8	0	47	0.002	24
B	24x18	4.712	12.567	-1.07	0.004	55	-0.089	8	0	47	0.001	24
A+B	2*0	0	0.174	-1.705	0		-0.005		0		0.002	
A+B	2*10x12	1.09	7.768	-1.6	-0.018		-0.028		0		0	
A+B	2*20x16	5.818	18.326	-1.535	-0.021		-0.048		0		0.002	
A+B	2*24x18	9.424	25.134	-1.35	-0.072		-0.09		-0.001		0.001	
A+B+Wall	2*24x18	9.424	25.134	-0.63	-0.01		-0.033		0		0.002	

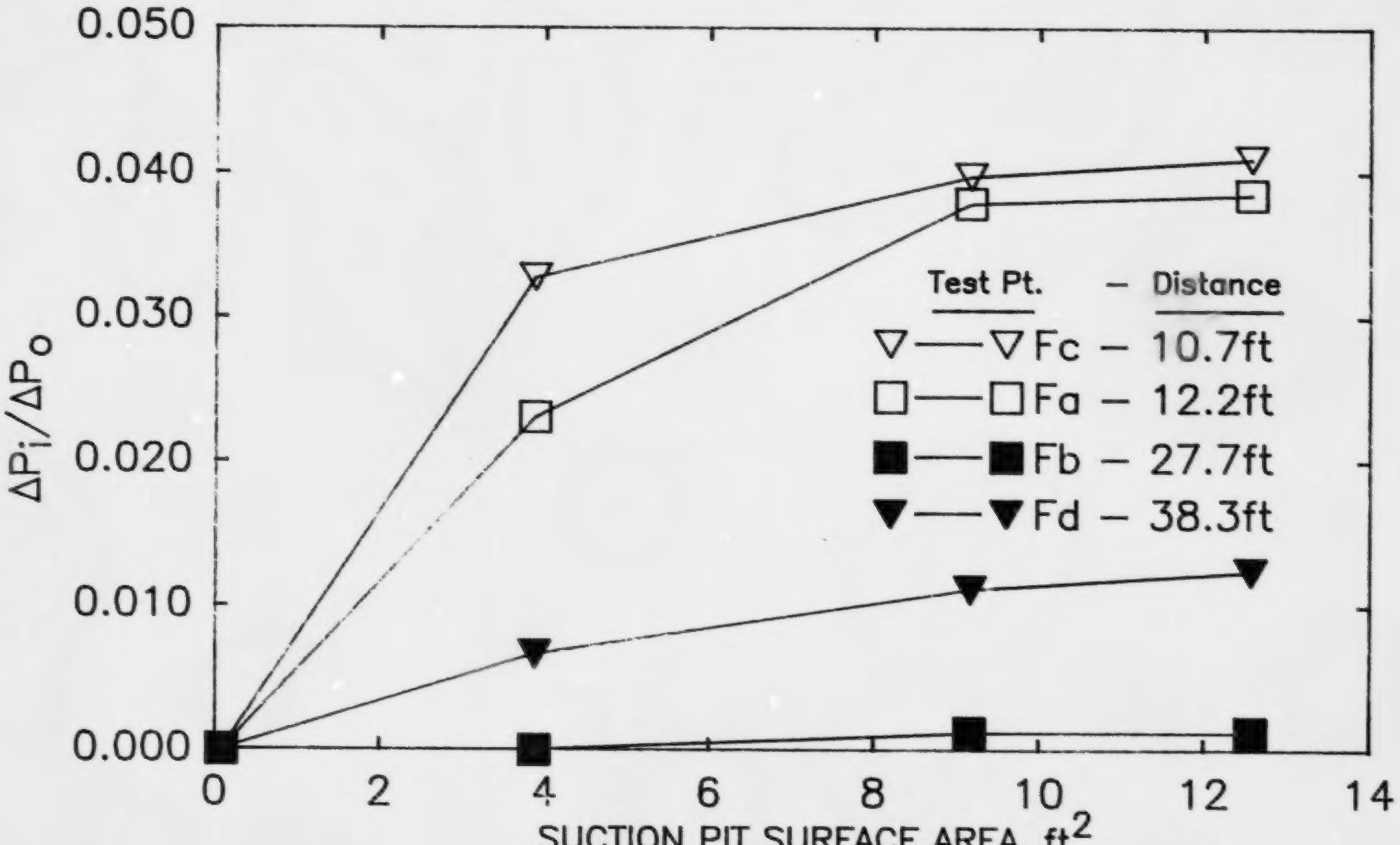


Figure 46. Relative sub–slab pressure vs suction hole–B surface area exposed, at house DW12.

With either of the suction points separately active, the sub-slab pressures were measurable only to a distance of about 8 ft from the suction hole. At some of the test points, the pressures were positive and slightly sensitive to the suction applied to the pit. The data from test points Fa and Fb are shown in Figure 47. In this figure the values of the pressures at the test points have been divided by the pressure at the corresponding suction point. Also shown in this figure are the data from these two test points with both suction pits A and B active. As seen from this figure, the communication improved continually as more soil was removed from the suction hole. Even after removing about 5 ft^3 (35 gallons) of soil, the communication was still improving at the test points Fa and Fb.

In summary, the communication under the slab improved with increasing suction hole size. The effects of hole shape were not tested at houses DW12 and DW14. However, based on the data obtained at houses DW43 and DW78 it appeared that the surface area of soil exposed in the pit was a more appropriate parameter than diameter in determining the ability of a suction hole to produce a measurable sub-slab pressure field.

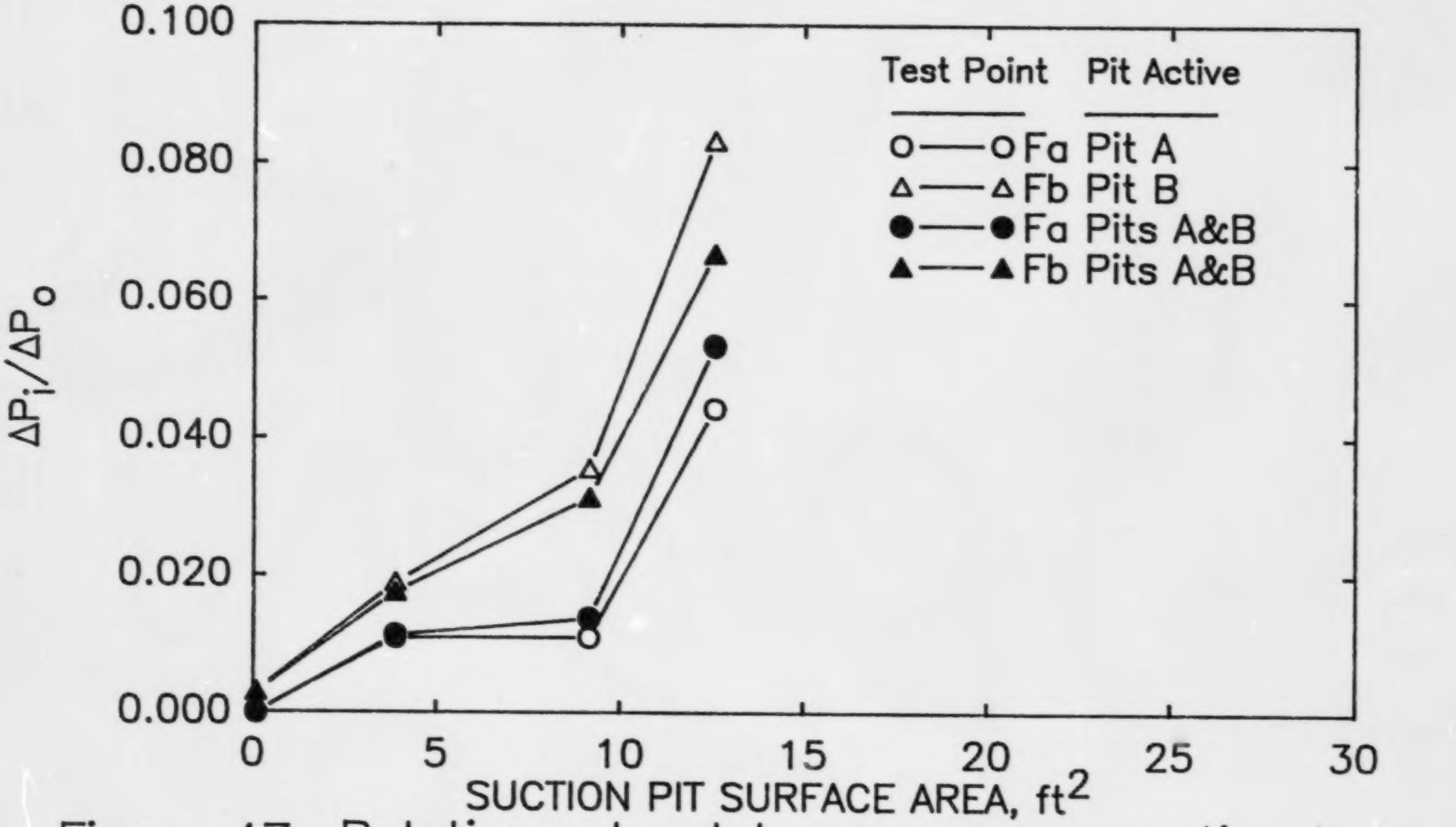


Figure 47. Relative sub–slab pressure vs suction hole surface area exposed, at house DW14.

SECTION 8

QUALITY ASSURANCE

This research program was part of a national radon mitigation effort for which overall standards have not been well defined. The purpose of the work carried out in this research project was to develop or demonstrate mitigation techniques which, at low to moderate cost, will have a high probability of reducing the average long-term radon concentrations to low levels (less than 4 pCi/L). This research project is designated as a Category III, Research and Development in Support of Technology Development[6]. The quality assurance objectives for accuracy, precision and completeness, are described in the Quality Assurance Project Plan (QAPP) dated December 10, 1987. The measurement procedures used and the accuracy and precision objectives for the data obtained from these measurements follow the protocols described in the EPA document entitled "Indoor Radon and Radon Decay Product Measurement Protocols[7]". Values for precision are given in terms of a coefficient of variation (1 sigma) expressed as a percent. Accuracy objectives are in terms of percent bias. The target completeness goal is the ratio of the number of measurements considered valid to the number of measurements planned and is expected to be 90% for each radon measurement method.

ALPHA TRACK DETECTORS

In April 1988, five "blind" alpha track detectors (ATDs) were exposed in the USEPA Eastern Environmental Radiation Facility (EERF) , Montgomery, AL to a radon level of 98.7 ± 4.5 pCi/L for a period of 7 days (690.9 ± 31.5 pCi/L-d). The other conditions in the radon chamber were: temperature = 70 ± 2 °F, and relative humidity = 80 ± 5 %. The detectors were then returned to the supplier (Tech/Ops Landaur, Inc., Glenwood, IL) for analysis. The results are shown in the first five entries of TABLE 24. In the initial results reported from the supplier, the readings ranged from 31.5 pCi/L-d to 294 pCi/L-d. After conversations with the supplier, it was discovered that the wrong side of the plastic detectors was read on three of the detectors (619095, 619075, and 619111). All five of the detectors were re-read and the second set of values in TABLE 24 were reported. The accuracy of the second set of results for the "wrong side read" detectors was marginally acceptable. No reason could be found for the gross errors of the two remaining detectors (796754 and 796774).

The "blind" ATD measurements were repeated in November 1989. The delay in repeating these tests was due mainly to the unavailability of the EERF chamber during the summer of 1988 when Round 5 of the EPA Radon Measurement Proficiency Program was underway. In November 1989 a total of 15 ATDs were exposed in the EERF chamber at three levels: 729.6 pCi/L-d, 1366.4 pCi/L-d, and 2349.7 pCi/L-d. The chamber conditions were as before, temperature = 70 ± 2 °F and relative humidity = 50 ± 5%. Following these exposures, the detectors were returned to the supplier (Tech/Ops Landaur, Inc., Glenwood, IL) for analysis. The reported results are shown in the lower portion of TABLE 24. The accuracy of these later "blinds" is much better than before. Using the same test criterion as that used in The National Radon Measurement Proficiency (RMP) Program[5], the mean of the absolute values of the relative errors (MARE), the precision of the "blinds" was calculated to be 8.9% which is well within the acceptable limits set in the RMP Program of 25% (using all detectors the MARE value is 18.6% and still within acceptable limits).

The large errors in the original detectors of TABLE 24 led to an investigation of possible errors in the field deployed ATDs. The complete set of collocated ATDs was examined and a sub-set consisting of seven collocated detector-pairs was identified that had reported results that differed between the paired detectors by more than the expected uncertainty (± 25%). These pairs of detectors were presented to the supplier for reevaluation without providing any additional information (such as CC or CRM values) other than the fact that they were collocated pairs. The response by the supplier is included in Appendix D. In essence, the response concluded that six of the paired detectors were invalid as a result of a "detector positioning and identity change that was implemented shortly before these detectors were fabricated". The results of these six detectors were voided and were not used in any of the calculations in the report.

A total of 17 ATDs were returned to the supplier as "blanks" over the period from April 1988 to January 1990. These detectors were handled just as those exposed in the field except that they were not exposed to any known elevated levels of radon. The results from all of these detectors were reported as less than 1.0 pCi/L (or 30 pCi/L-d). This value represents the lower level of sensitivity for the ATDs, as quoted in the manufacturer's literature (sensitivity can be increased to 0.2 pCi/L or 6 pCi/L-d for additional charges per detector of $60).

Of the remaining ATDs used to date, 146 detectors have been installed and retrieved from the field. In every location duplicate collocated detectors were used. Out of this 146 detectors, six were found to be invalid as described above. Of the remaining 132 detectors, or 66 pairs, the average coefficient of variation was found to be 14.1% which was within the precision expected in the QAPP for this project. Discarding the detectors that were collocated with each of the six defective detectors gave a completeness factor of 92 % or within that expected in the QAPP.

In summary, for the ATDs, we discovered large errors which appear attributable to incorrect procedures in manufacturing and/or in reading the detectors. These errors were characterized by extremely low values of radon (approximately 5% of the expected level). If this were the only type of errouneous reading they could possibly be flagged and rejected as outliers. We also noted large negative biases (averaging -37%) on sets where correct procedures were supposedly followed by the manufacturer. These problems appear to have been corrected sometime before the 1989 "blinds" were analyzed. As a result, the following corrective actions were taken:

- The manufactured was contacted and asked to reread the "blinds" and other suspect detectors
- The "blinds" were repeated
- The type of device used was changed from DSF to DRN

- Short term CRM data was used primarily for evaluation of the mitigation effectiveness.

In consequence of these findings, our assessment of the quality of the ATD data is as follows:

- In the absence of flaggable problems the precision of the measurements is marginally acceptable
- The accuracy of earlier detectors appears to be off by a bias of greater than the 25% target value.
- If the results are used without correction the estimates of mitigation effectiveness using long term measurements will be conservative. The pre-mitigation measurements will be biases low, while many of the post-mitigation measurements will have a smaller net bias.

TABLE 24. ALPHA TRACK DETECTOR BLINDS

Detector ID	Detector Type	Actual Exposure pCi/L-d	Initial Reported Exposure pCi/L-d	Percent Error	Second Reported Exposure pCi/L-d	Percent Error
619095	DSF	690.9	49	-92.9	560	-18.9
619075	DSF	690.9	31.5	-95.4	549.5	-20.5
619111	DSF	690.9	31.5	-95.4	490	-29.1
796754	DSF	690.9	294	-57.4	294	-57.4 *
796774	DSF	690.9	269.5	-61.0	269.5	-61.0 *
796566	DSF	729.6	765.2	+ 4.9		
1036236	DRN	729.6	753.0	+ 3.2		
1580763	DRN	729.6	651.2	-10.7		
1652950	DRN	729.6	791.1	+ 8.4		
1654750	DRN	729.6	643.1	-11.8		
1655296	DRN	729.6	767.4	+ 5.2		
1656243	DRN	729.6	690.6	- 5.3		
1658311	DRN	729.6	690.6	- 5.3		
1660900	DRN	729.6	705.2	- 3.3		
796572	DSF	1366.4	1384.4	+ 1.3		
1036237	DRN	1366.4	1278.3	- 6.4		
1580810	DRN	1366.4	1179.3	-13.7		
1652988	DRN	1366.4	1302.7	- 4.7		
1654773	DRN	2349.7	2213.5	- 5.8		
1662119	DRN	2349.7	2298.5	- 2.2		
			MARE =	8.9		

* - Not used in calculating the MARE (mean absolute relative error)

CHARCOAL CANISTERS

In January 1988, five charcoal canister (CC) detectors were exposed as "blinds" for two days in the radon chamber at EERF. The radon level in the chamber was held to 34.0 ± 0.7 pCi/L at a temperature of 70 ± 2 °F and at a relative humidity of 15 ± 5 %. The total exposure for the five CCs was 67.9 pCi/L-d. The canisters were then returned to the supplier (Scientific Analysis, Inc., Montgomery, AL) for analysis. The reported results are shown in TABLE 25 along with the percent error, the reported weight change of the CCs, and the mean absolute relative error (MARE).

It is evident that the "blinds" exceeded the expected accuracy of ± 25%, as described in the QAPP. Discussions with the supplier (see Memo dated 2/4/88 included in Appendix D) resulted in the conclusion that the relative humidity in the chamber was so low that the CCs lost moisture and exceeded the collection efficiency for radon gas used in calibrations. Also, there were some unresolved questions regarding the velocity of the chamber air in the vicinity of the canisters. The effects of the air velocity across the canister face are thought to influence the adsorption efficiency of the device. As the velocity increases, the device records a higher than normal radon level. However, no absolute resolution of the large errors was obtained from these discussions.

On April 8, 1988 additional charcoal canisters were sent to EERF (see letter to Mr. Sensintaffer in Appendix D) for exposure at higher relative humidities (50 to 80%) and in locations such that the air velocity over half of the detectors was high and over the remainder was very low. Unfortunately, the detectors were misplaced by EERF and never exposed. Apparently EERF had independently concluded that there was a problem with regards to canister placement in the chamber and the air velocities at various locations in the chamber. The CC "blinds" were scheduled to be repeated in the summer of 1988, however, the EERF chamber was unavailable due to preparations for Round 5 of the RMP Program. In the ensuing months, the repeat of the "blind" measurements was completely overlooked. Due to the fact that the CC "blinds" issue was not resolved, no corrections were made to the data from other CC measurements. Instead, the accuracy of the CC measurements was monitored by simultaneous measurements with a continuous radon monitor (CRM).

Four CC detectors were returned to the supplier as "blanks". The reported radon levels from these detectors were all less than 0.2 pCi/L which was close to or less than the lower limit of detectability.

A total of 180 CC measurements were carried out in the field. Of this number, 124 were pre-mitigation measurements and 56 were post-mitigation measurements. In all but one instance, duplicate collocated measurements were carried out. In two other cases the paired measurements were flawed by error, in one instance one of the CCs was lost and in another the CC was returned to the supplier minus the lid. Thus, the completeness of the CC measurements was well within the 90% objective of the QAPP. For the remaining 87 pairs of collocated CCs the coefficient of variation in the measurements ranged from a low of 0% to a high of 29.8% with an average of 2.5%. This average was well below the value of 10% anticipated in the QAPP.

In summary, QC checks on the CC measurements revealed excellent precision and questionable accuracy. Our personel assessment of the quality of the CC data is that the accuracy of the field data is within our QA objectives without correction. We believe that the "blind" data is flawed by the exposure conditions, however, we cannot support this conclusion without repeated "blind" testing.

TABLE 25. CHARCOAL CANISTER BLINDS

Detector ID	Actual Exposure (pCi/L-d)	Reported Exposure (pCi/L-d)	Percent Error (%)	Weight Gain (gr)
D-3086	67.88	94	+38.5	-1.1
D-3095	67.88	93.2	+37.3	-1.2
D-3098	67.88	93.4	+37.6	-1.1
D-3101	67.88	98	+44.4	-1.1
D-3106	67.88	93.2	+37.3	-1.1
		MARE =	39.01	

CONTINUOUS RADON MONITORS

The measurements of radon levels in the houses on a continuous basis were carried out with Pylon continuous monitors (AB-5) equipped with passive scintillation cells (PRD-1). These units were calibrated twice during the project. The first calibration was carried out in January 1988 at the EERF radon chamber. The second calibration was accomplished in June 1988 in the same location. From each sets of data the instrument calibration factors were calculated. These results are shown in TABLE 26.

The variation in the values of the calibration factors determined from known radon levels were well within the precision anticipated in the QAPP for this critical measurement. The accuracy of the CRMs was measured by placing all four instruments in a chamber of known radon level. The results are also shown in TABLE 26. The MARE of the CRMs was 5% which is better than the ATD value. The uncertainty of a particular measurement with the CRMs varies from -1.7% to -7.3% depending upon which instrument is used. Because of the changing nature of the field radon levels and due to the fact that no duplicate CRM measurements were feasible in the field (no two instruments were ever available at the same time), no measurement of the precision or accuracy of the continuous monitors as deployed in the field was possible. Therefore, the results of the collocated chamber measurements shown in TABLE 26 are assumed to represent the precision and accuracy of the CRMs. As anticipated, the measurements are well within the QA objectives for this device.

TABLE 26. CONTINUOUS PASSIVE RADON DETECTOR CALIBRATIONS AND PRECISION MEASUREMENTS

Unit ID #	Serial No.	CF 1/20/88	Actual Radon Level (pCi/L)	Reported Radon Level (pCi/L)	Error (%)	CF 6/23/88
AB-5/1 PRD-1	382 165	1.10	17.9	17.6	-1.7	1.07
AB-5/2 PRD-1	387 163	1.22	17.9	16.7	-6.7	1.15
AB-5/3 PRD-1	389 167	1.10	17.9	16.6	-7.3	1.01
AB-5/4 PRD-1	404 208	1.16	17.9	17.1	-4.5	1.10
					MARE = 5.0	

MARE = Mean absolute relative error
CF = Calibration factor in cpm/pCi/L

The QAPP for this project called for a technical systems audit of the project "about midway through the project". The informal audit was not adequately documented, and dealt primarily with data quality assessment in light of the difficulties which had occurred with the CC and ATD measurements. In brief, the project manager approved, and participated in, development of the corrective actions taken with regards to both samples, and directed that memos and copies of correspondence be kept in the project QA file.

REFERENCES

1. "Summary Report of the Tennessee Radon Survey", Tennessee Department of Health and Environment, Division of Air Pollution Control, Nashville, TN, August 1987.

2. "Single Family Detached Housing Construction Characteristics", National Association of Home Builders Research Foundation, Inc., report prepared for American ATCON, Inc., October 1985.

3. "Building Foundation Design Handbook", Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/Sub/86-72143/1, May 1988.

4. "The Radon Sampling Project Final Report", Regional Air Pollution Control Agency: Dayton, OH, December 1986, pp. 15-21.

5. Ericson, S. and H. Schmied. "Modified Design in New Construction Prevents Infiltration of Soil Gas Carrying Radon". Proceedings of the ACS Symposium on Radon and its Decay Products: Occurrence, Properties, and Health Effects. April 1986, pp 5-6.

6. "AEERL Quailty Assurance Procedures Manual For Contractors and Financial Assistance Recipients", AEERL, U.S. Environmental Protection Agency, Research Triangle Park, NC, First Draft, July 20, 1987.

7. "Indoor Radon and Radon Decay Product Measurement Protocols", U.S. Environmental Protection Agency, Office of Radiation Programs, Eastern Environmental Radiation Facility, Las Vegas Facility, Las Vegas, NV, (EPA 520-1/89-009; NTIS PB89-224273), February 1989.

AGREEMENT NO._____

BETWEEN

SOUTHERN RESEARCH INSTITUTE (SRI)

AND

____

This Agreement is made and entered into between Southern Research Institute ("SRI") and the undersigned owners/tenants residing in the house and lands located at:

____ ("Residents").

1. The undersigned Residents understand that radon is a radioactive gas produced by the natural breakdown of the substance uranium. Residents further understand that radon seeps naturally from the soil and sometimes accumulates in enclosed spaces such as houses, Residents further understand that the presence of radon gas has been detected in their house at the above-listed address. The undersigned SRI is interested in the development of low-cost methods of mitigating radon gas concentrations which may be found in homes.

2. The undersigned Residents agree to participate in a study sponsored by the U. S. Environmental Protection Agency ("EPA") and conducted by SRI to develop experimental low-cost radon mitigation methods for homes. Residents hereby authorize SRI, its representatives, and its subcontractors to enter onto their premises, take measurements, and make determinations of what devices and methods may best be used to locate and mitigate radon presence within their house and/or on the above premises.

3. Residents understand that this Agreement authorizes SRI, its representatives, and its subcontractors to have access to their house for a period beginning __________________________ and continuing through __________________________, at no cost to SRI or the EPA. Residents agree to cooperate with SRI, its representatives, and its subcontractors to provide access to the premises during reasonable hours. SRI agrees to provide reasonable notice, whenever possible, before coming onto the premises.

4. Residents realize that for effective mitigation, SRI may be required to modify the house design and/or structure in order to install its mitigation devices. Residents understand that any modifications contemplated for the design and/or structure of the premises shall be explained to them beforehand and shall be subject to their prior approval, in writing. SRI agrees that if

the modification results in any damage to the premises, it will make reasonable repairs at no cost to Residents.

5. SRI will experiment with methods to reduce the radon level in the house to a level at or below 4pCi/l. However, Residents understand that this is an experimental study, and that SRI does not and cannot warrant that radon levels in the above premises can be or will be reduced. Residents understand that the process of installing mitigation equipment may result in a temporary increase in radon concentrations on the premises, but that SRI, its representatives, and subcontractors will take all reasonable steps to keep the radon level as low as possible during the study.

6. In consideration of Residents being selected to participate in this study, they agree to release, waive and forever hold harmless SRI, its representatives and subcontractors, and the EPA for any physical harm, foreseeable or unforeseeable, which may occur as a result of any act, omission, activity, process or system employed in connection with this study, including, without limitation, physical injuries on the premises, potential detrimental effects of radon, whether by exposure or by other means direct or indirect, or any other condition or ailment related in any way to this study.

7. SRI agrees to treat the data and the identity of the Residents as confidential. All reports to parties other than the EPA will be coded to prevent recognition of the premises involved in the study.

8. The undersigned parties agree that any mitigation devices or installations may remain attached to the premises, and will become the property of the owner at the end of the study upon the execution by Residents of a Conveyance Agreement (a copy of which is attached as Exhibit "A") in which case SRI and the EPA shall have no responsibility or liability for the maintenance of such devices or their subsequent use or removal. Residents understand that if they wish for the devices to be removed at the end of the study, SRI will use its best efforts to return the house to an "as found" condition, at no cost to Residents.

9. The undersigned parties agree that the invalidation of any provision outlined above shall not invalidate any other provisions of this Agreement, which provisions shall continue in full force and effect. The parties further agree that this instrument states the full agreement between them, supersedes any previous agreements, and shall not be modified except by subsequent agreement, in writing, signed by all parties.

Executed and entered into as of the _____ day of ________________, 19____.

WITNESS:

SOUTHERN RESEARCH INSTITUTE

____

____
Authorized Agent

____

____
Owner/Tenant

____

____
Owner/Tenant

EXHIBIT "A"

CONVEYANCE AGREEMENT

This agreement is made and entered into by and between Southern Research Institute (SRI), grantor, and ____________________ ____, grantees.

For and in consideration for the participation of grantees in a study of mitigation methods for radon concentrations in the premises located at ______________________________________, pursuant to the terms of an Agreement dated ____________________, 19____, the undersigned grantor SRI does hereby grant, bargain, sell and convey unto grantees all of the equipment, systems and structural modifications ("the equipment") previously installed in said premises in connection with said study, to have and to hold unto the said grantees, their heirs, executors, successors, transfers and assigns, forever.

For and in consideration of the conveyance of said equipment, receipt whereof is hereby acknowledged, the undersigned grantees do hereby accept said equipment "as-is" and without any warranties, guarantees or promises, express or implied, except for any manufacturers' warranties which may inure to the benefit of the grantees upon transfer of title pursuant to this instrument. And grantees, for themselves, their heirs, executors, successors, transfers and assigns, do further accept full liability for any and all future maintenance, uses or removal of said equipment on the premises, and do hereby release, waive and forever discharge SRI, its representatives and subcontractors, and the U.S. Environmental Protection Agency from any action, claim or demand by them, known or unknown, in contract or in tort, arising from or in any way related to the installation of said equipment or the modification of the structure of said premises, to include, without limitation, any and all claims for trespass, property damage, breach of warranty or breach of contract.

Executed and entered into as of the _____ day of ____________________, 19____.

WITNESS:

____

____

____

SOUTHERN RESEARCH INSTITUTE

____
Authorized Agent

____
Owner/Tenant

____
Owner/Tenant

MITIGATION DESIGN APPROVAL

The undersigned owners/tenants have seen the mitigation design and/or structure modification (attached as Exhibit A) for the premises at ____ in accordance with Agreement Number ______ between SRI and the owners/tenants. This mitigation design and/or structure modification has been thoroughly and completely explained by SRI to our satisfaction and approval.

We hereby authorize SRI to undertake mitigation and/or structure modification of the premises.

________________________ Witness	________________________ Owner/Tenant
________________________ Witness	________________________ Owner/Tenant
	________________________ Date of Execution

APPENDIX B

CONTINUOUS RADON MONITOR DATA

The following lists contain the data obtained with the Pylon AB-5 radon monitor with the PRD-1 passive cell attached. The data were taken over the period beginning November 29, 1987 through April 26, 1988 in the demonstration houses in the Nashville, TN area.

House DW 03 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	04/08/88		0.00	Note: Counts
2	01:00	Friday		0.00	are actually 30 min.
3	02:00			0.00	later
4	03:00			0.00	
5	04:00			0.00	
6	05:00			0.00	
7	06:00			0.00	
8	07:00			0.00	
9	08:00			0.00	
10	09:00			0.00	
11	10:00			0.00	
12	11:00			0.00	
13	12:00			0.00	AB5 #4
14	13:00			0.00	1st Ct.at 2:30pm
15	14:00		175	2.19	Start Pre-Mit
16	15:00		246	3.21	Monitoring 1337
17	16:00		197	2.50	
18	17:00		212	2.72	
19	18:00		158	1.94	
20	19:00		168	2.09	
21	20:00		209	2.67	
22	21:00		234	3.03	
23	22:00		249	3.25	
24	23:00		297	3.94	
25	00:00	04/09/88	336	4.50	
26	01:00	Saturday	414	5.62	
27	02:00		522	7.17	
28	03:00		580	8.00	
29	04:00		613	8.48	
30	05:00		615	8.51	
31	06:00		685	9.51	
32	07:00		750	10.45	
33	08:00		788	10.99	
34	09:00		786	10.96	
35	10:00		738	10.27	
36	11:00		720	10.02	
37	12:00		687	9.54	
38	13:00		556	7.66	
39	14:00		535	7.36	
40	15:00		452	6.17	
41	16:00		394	5.33	
42	17:00		349	4.69	
43	18:00		314	4.18	
44	19:00		266	3.49	

DW 03

```
45   20:00             238    3.09
46   21:00             245    3.19
47   22:00             278    3.67
48   23:00             300    3.98
49   00:00 04/10/88    283    3.74
50   01:00 Sunday      387    5.23
51   02:00             432    5.88
52   03:00             506    6.94
53   04:00             559    7.70
54   05:00             654    9.07
55   06:00             732   10.19
56   07:00             757   10.55
57   08:00             822   11.48
58   09:00             831   11.61
59   10:00             802   11.19
60   11:00             836   11.68
61   12:00             774   10.79
62   13:00             677    9.40
63   14:00             655    9.08
64   15:00             556    7.66
65   16:00             542    7.46
66   17:00             470    6.42
67   18:00             432    5.88
68   19:00             402    5.45
69   20:00             396    5.36
70   21:00             375    5.06
71   22:00             391    5.29
72   23:00             375    5.06
73   00:00 04/11/88    434    5.91
74   01:00 Monday      462    6.31
75   02:00             473    6.47
76   03:00             533    7.33 Pre-Mit Level
77   04:00             481    6.58 For 17-81
78   05:00             550    7.57 Minimum=     1.94 pCi/l
79   06:00             573    7.90 Maximum=    11.68
80   07:00             628    8.69 Average=     6.82
81   08:00             660    9.15 Std.Dev.=    2.75
82   09:00             630    8.72 Begin SPS Install
83   10:00             681    9.46  9:30 am
84   11:00             677    9.40 stop cc 1011
85   12:00             638    8.84
86   13:00             535    7.36
87   14:00             477    6.52
88   15:00             452    6.17
89   16:00             401    5.43
90   17:00             383    5.17
91   18:00             344    4.61
92   19:00             265    3.48
93   20:00             271    3.56
94   21:00             254    3.32
95   22:00             236    3.06
```

DW 03

96	23:00		285	3.77	
97	00:00	04/12/88	245	3.19	
98	01:00	Tuesday	323	4.31	
99	02:00		292	3.87	
100	03:00		351	4.71	
101	04:00		331	4.43	
102	05:00		312	4.15	
103	06:00		266	3.49	
104	07:00		244	3.18	
105	08:00		224	2.89	
106	09:00		267	3.51	
107	10:00		211	2.70	
108	11:00		218	2.80	
109	12:00		180	2.26	
110	13:00		145	1.75	
111	14:00		162	2.00	Complete Install
112	15:00		154	1.88	at 2:00pm
113	16:00		116	1.34	
114	17:00		123	1.44	
115	18:00		89	0.95	Fan Off Passive
116	19:00		93	1.01	Vent Only
117	20:00		107	1.21	
118	21:00		126	1.48	
119	22:00		137	1.64	
120	23:00		156	1.91	
121	00:00	04/13/88	222	2.86	
122	01:00	Wednesday	250	3.26	
123	02:00		313	4.17	
124	03:00		353	4.74	
125	04:00		390	5.27	
126	05:00		480	6.57	
127	06:00		558	7.69	
128	07:00		597	8.25	
129	08:00		594	8.21	
130	09:00		687	9.54	
131	10:00		645	8.94	
132	11:00		613	8.48	
133	12:00		580	8.00	
134	13:00		453	6.18	
135	14:00		431	5.86	
136	15:00		347	4.66	
137	16:00		239	3.11	
138	17:00		225	2.90	
139	18:00		226	2.92	
140	19:00		198	2.52	
141	20:00		196	2.49	
142	21:00		210	2.69	
143	22:00		191	2.42	
144	23:00		264	3.46	
145	00:00	04/14/88	269	3.54	
146	01:00	Thursday	327	4.37	

DW 03

147	02:00		332	4.44
148	03:00		406	5.50
149	04:00		458	6.25
150	05:00		575	7.93
151	06:00		602	8.32
152	07:00		676	9.38
153	08:00		660	9.15
154	09:00		660	9.15
155	10:00		677	9.40
156	11:00		632	8.75
157	12:00		534	7.34
158	13:00		471	6.44
159	14:00		391	5.29
160	15:00		276	3.64
161	16:00		226	2.92
162	17:00		174	2.17
163	18:00		121	1.41
164	19:00		97	1.06
165	20:00		64	0.59
166	21:00		101	1.12
167	22:00		75	0.75
168	23:00		73	0.72
169	00:00	04/15/88	73	0.72
170	01:00	Friday	85	0.89
171	02:00		98	1.08
172	03:00		140	1.68
173	04:00		153	1.87
174	05:00		185	2.33
175	06:00		243	3.16
176	07:00		273	3.59
177	08:00		316	4.21
178	09:00		266	3.49
179	10:00		303	4.02
180	11:00		343	4.60
181	12:00		257	3.36
182	13:00		263	3.45
183	14:00		232	3.00
184	15:00		252	3.29
185	16:00		236	3.06
186	17:00		232	3.00
187	18:00		288	3.81
188	19:00		327	4.37
189	20:00		328	4.38
190	21:00		362	4.87
191	22:00		384	5.19
192	23:00		454	6.19
193	00:00	04/16/88	510	7.00
194	01:00	Saturday	555	7.65
195	02:00		559	7.70
196	03:00		683	9.48
197	04:00		689	9.57

DW 03

198	05:00		770	10.73
199	06:00		797	11.12
200	07:00		849	11.87
201	08:00		773	10.78
202	09:00		836	11.68
203	10:00		815	11.38
204	11:00		789	11.01
205	12:00		695	9.66
206	13:00		582	8.03
207	14:00		528	7.26
208	15:00		459	6.27
209	16:00		408	5.53
210	17:00		327	4.37
211	18:00		348	4.67
212	19:00		275	3.62
213	20:00		286	3.78
214	21:00		314	4.18
215	22:00		415	5.63
216	23:00		419	5.69
217	00:00	04/17/88	459	6.27
218	01:00	Sunday	563	7.76
219	02:00		671	9.31
220	03:00		713	9.92
221	04:00		771	10.75
222	05:00		830	11.60
223	06:00		851	11.90
224	07:00		860	12.03
225	08:00		933	13.08
226	09:00		979	13.74
227	10:00		904	12.66
228	11:00		923	12.93
229	12:00		852	11.91
230	13:00		784	10.94
231	14:00		641	8.88
232	15:00		571	7.88
233	16:00		535	7.36
234	17:00		421	5.72
235	18:00		381	5.15
236	19:00		367	4.94
237	20:00		294	3.90
238	21:00		317	4.23
239	22:00		337	4.51
240	23:00		345	4.63
241	00:00	04/18/88	398	5.39
242	01:00	Monday	424	5.76
243	02:00		462	6.31
244	03:00		430	5.85
245	04:00		495	6.78
246	05:00		532	7.31
247	06:00		584	8.06
248	07:00		704	9.79

DW 03

```
249   08:00                 685    9.51
250   09:00                 669    9.28
251   10:00                 575    7.93
252   11:00                 389    5.26
253   12:00                 290    3.84
254   13:00                 216    2.77
255   14:00                 187    2.36
256   15:00                 132    1.57
257   16:00                 112    1.28
258   17:00                  88    0.94
259   18:00                  98    1.08
260   19:00                 101    1.12
261   20:00                 132    1.57
262   21:00                 171    2.13
263   22:00                 194    2.46
264   23:00                 239    3.11
265   00:00 04/19/88        254    3.32
266   01:00 Tuesday         277    3.65
267   02:00                 331    4.43
268   03:00                 331    4.43
269   04:00                 338    4.53
270   05:00                 335    4.48 Seal/vent level
271   06:00                 394    5.33 For 115-274
272   07:00                 372    5.02 Maximum-    13.74 pCi/l
273   08:00                 370    4.99 Minimum-     0.59
274   09:00                 366    4.93 Average-     5.56
275   10:00                 322    4.30 Std.Dev.-    3.26
276   11:00                 274    3.61 SPS Fan on 10am
277   12:00                 298    3.95
278   13:00                 227    2.93
279   14:00                 195    2.47
280   15:00                 179    2.24
281   16:00                 165    2.04
282   17:00                 140    1.68
283   18:00                 136    1.63
284   19:00                 101    1.12
285   20:00                 108    1.22
286   21:00                 123    1.44
287   22:00                 153    1.87
288   23:00                 190    2.40
289   00:00 04/20/88        189    2.39
290   01:00 Wednesday       218    2.80
291   02:00                 209    2.67
292   03:00                 229    2.96
293   04:00                 201    2.56
294   05:00                 220    2.83
295   06:00                 219    2.82
296   07:00                 199    2.53
297   08:00                 200    2.54
298   09:00                 180    2.26
299   10:00                 142    1.71
```

DW 03

300	11:00		146	1.77
301	12:00		138	1.65
302	13:00		112	1.28
303	14:00		131	1.55
304	15:00		96	1.05
305	16:00		70	0.68
306	17:00		92	0.99
307	18:00		81	0.84
308	19:00		85	0.89
309	20:00		101	1.12
310	21:00		111	1.27
311	22:00		139	1.67
312	23:00		137	1.64
313	00:00	04/21/88	147	1.78
314	01:00	Thursday	116	1.34
315	02:00		132	1.57
316	03:00		111	1.27
317	04:00		131	1.55
318	05:00		115	1.32
319	06:00		146	1.77
320	07:00		138	1.65
321	08:00		127	1.50
322	09:00		117	1.35
323	10:00		134	1.60
324	11:00		117	1.35
325	12:00		117	1.35
326	13:00		117	1.35
327	14:00		82	0.85
328	15:00		81	0.84
329	16:00		85	0.89
330	17:00		90	0.96
331	18:00		94	1.02
332	19:00		66	0.62
333	20:00		74	0.73
334	21:00		66	0.62
335	22:00		64	0.59
336	23:00		81	0.84
337	00:00	04/22/88	64	0.59
338	01:00	Friday	96	1.05
339	02:00		82	0.85
340	03:00		92	0.99
341	04:00		108	1.22
342	05:00		84	0.88
343	06:00		112	1.28
344	07:00		111	1.27
345	08:00		128	1.51
346	09:00		121	1.41
347	10:00		110	1.25
348	11:00		102	1.14
349	12:00		100	1.11
350	13:00		82	0.85

DW 03

351	14:00		74	0.73	
352	15:00		67	0.63	
353	16:00		47	0.35	
354	17:00		68	0.65	
355	18:00		58	0.50	
356	19:00		60	0.53	
357	20:00		56	0.48	
358	21:00		55	0.46	
359	22:00		58	0.50	
360	23:00		62	0.56	
361	00:00	04/23/88	60	0.53	
362	01:00	Saturday	59	0.52	
363	02:00		61	0.55	
364	03:00		55	0.46	
365	04:00		78	0.79	
366	05:00		80	0.82	
367	06:00		98	1.08	
368	07:00		70	0.68	
369	08:00		90	0.96	
370	09:00		81	0.84	
371	10:00		62	0.56	
372	11:00		65	0.61	
373	12:00		57	0.49	
374	13:00		47	0.35	
375	14:00		61	0.55	
376	15:00		39	0.23	
377	16:00		34	0.16	
378	17:00		41	0.26	
379	18:00		45	0.32	
380	19:00		46	0.33	
381	20:00		34	0.16	
382	21:00		63	0.58	
383	22:00		46	0.33	
384	23:00		58	0.50	
385	00:00	04/24/88	55	0.46	
386	01:00	Sunday	73	0.72	
387	02:00		70	0.68	
388	03:00		90	0.96	
389	04:00		105	1.18	
390	05:00		122	1.42	
391	06:00		134	1.60	
392	07:00		154	1.88	
393	08:00		136	1.63	
394	09:00		171	2.13	
395	10:00		142	1.71	
396	11:00		138	1.65	
397	12:00		135	1.61	
398	13:00		141	1.70	start post-mit
399	14:00		121	1.41	CC 1300
400	15:00		128	1.51	
401	16:00		97	1.06	

DW 03

```
 402   17:00                 95     1.04
 403   18:00                 75     0.75
 404   19:00                 76     0.76
 405   20:00                103     1.15
 406   21:00                 95     1.04
 407   22:00                117     1.35
 408   23:00                156     1.91
 409   00:00 04/25/88       158     1.94
 410   01:00 Monday         184     2.31
 411   02:00                205     2.62
 412   03:00                194     2.46
 413   04:00                226     2.92
 414   05:00                275     3.62
 415   06:00                239     3.11
 416   07:00                257     3.36
 417   08:00                241     3.13
 418   09:00                205     2.62
 419   10:00                221     2.85
 420   11:00                200     2.54
 421   12:00                166     2.06
 422   13:00                151     1.84
 423   14:00                124     1.45
 424   15:00                126     1.48
 425   16:00                134     1.60
 426   17:00                124     1.45
 427   18:00                144     1.74
 428   19:00                136     1.63
 429   20:00                147     1.78
 430   21:00                147     1.78
 431   22:00                169     2.10
 432   23:00                201     2.56
 433   00:00 04/26/88       156     1.91
 434   01:00 Tuesday        184     2.31
 435   02:00                212     2.72
 436   03:00                207     2.65
 437   04:00                202     2.57
 438   05:00                252     3.29
 439   06:00                230     2.98 Ave SPS level
 440   07:00                222     2.86 For 278-445
 441   08:00                226     2.92 Maximum-     3.62 pCi/l
 442   09:00                219     2.82 Minimum-     0.16
 443   10:00                216     2.77 Average-     1.48
 444   11:00                180     2.26 Std.Dev.-    0.81
 445   12:00                175     2.19 Stop Post-Mit Monitoring
                                         stop CC 1259 hrs
                                         Level during CC meas (398-4
                                         Minimum-     0.75 pCi/l
                                         Maximum-     3.62
                                         Average-     2.14
                                         Std.Dev.-    0.72
```

DW 03

Dp Measurements for Sub-poly suction systems.

Distance from Suction Point (ft)	Dp (inches of water) DW03
0	-1.551
2	-0.2
3	
4	
6	-0.003
12	-0.001
Q(cfm)	37.1

House DW 12 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	02/05/88	0		
2	01:00	Friday	0		
3	02:00		0		
4	03:00		0		
5	04:00		0		
6	05:00		0		
7	06:00		0		
8	07:00		0		
9	08:00		0		
10	09:00		0		
11	10:00		0		
12	11:00		0		
13	12:00		0		
14	13:00		0		
15	14:00		0		Start Pre-Mit
16	15:00		571	7.88	Monitoring
17	16:00		898	12.57	AB5 #4
18	17:00		1034	14.53	
19	18:00		1109	15.61	
20	19:00		1113	15.66	
21	20:00		1078	15.16	
22	21:00		1133	15.95	
23	22:00		1200	16.91	
24	23:00		1127	15.86	
25	00:00	02/06/88	1197	16.87	
26	01:00	Saturday	1256	17.72	
27	02:00		1290	18.21	
28	03:00		1243	17.53	
29	04:00		1187	16.73	
30	05:00		1127	15.86	
31	06:00		1160	16.34	
32	07:00		1190	16.77	
33	08:00		1136	15.99	
34	09:00		1153	16.24	
35	10:00		1102	15.50	
36	11:00		1057	14.86	
37	12:00		1050	14.76	
38	13:00		949	13.31	
39	14:00		980	13.75	
40	15:00		909	12.73	
41	16:00		908	12.72	
42	17:00		884	12.37	
43	18:00		891	12.47	
44	19:00		873	12.21	

DW 12

45	20:00		853	11.93	
46	21:00		927	12.99	
47	22:00		968	13.58	
48	23:00		1002	14.07	
49	00:00	02/07/88	955	13.39	
50	01:00	Sunday	1000	14.04	
51	02:00		1034	14.53	
52	03:00		1047	14.71	
53	04:00		947	13.28	
54	05:00		922	12.92	
55	06:00		877	12.27	
56	07:00		870	12.17	
57	08:00		916	12.83	
58	09:00		954	13.38	
59	10:00		863	12.07	
60	11:00		741	10.32	
61	12:00		633	8.77	
62	13:00		561	7.73	
63	14:00		575	7.93	
64	15:00		539	7.42	
65	16:00		512	7.03	
66	17:00		474	6.48	
67	18:00		487	6.67	
68	19:00		520	7.14	
69	20:00		478	6.54	
70	21:00		481	6.58	
71	22:00		549	7.56	
72	23:00		547	7.53	
73	00:00	02/08/88	548	7.54	
74	01:00	Monday	501	6.87	
75	02:00		551	7.59	
76	03:00		547	7.53	
77	04:00		523	7.19	
78	05:00		510	7.00	
79	06:00		553	7.62	Pre-mit levels
80	07:00		532	7.31	For 18-84
81	08:00		578	7.98	Minimum= 6.48 pCi/l
82	09:00		547	7.53	Maximum= 18.21
83	10:00		552	7.60	Average= 11.91
84	11:00		574	7.92	Std.Dev.= 3.71
85	12:00		490	6.71	
86	13:00		462	6.31	
87	14:00		402	5.45	Start Mit Insta
88	15:00		183	2.30	Basement open
89	16:00		93	1.01	
90	17:00		67	0.63	
91	18:00		61	0.55	
92	19:00		142	1.71	
93	20:00		291	3.85	
94	21:00		424	5.76	
95	22:00		536	7.37	

DW 12

96	23:00		623	8.62	
97	00:00	02/09/88	719	10.00	
98	01:00	Tuesday	725	10.09	
99	02:00		780	10.88	
100	03:00		732	10.19	
101	04:00		770	10.73	
102	05:00		671	9.31	
103	06:00		663	9.20	
104	07:00		662	9.18	
105	08:00		649	9.00	Start work
106	09:00		620	8.58	
107	10:00		441	6.01	
108	11:00		231	2.99	
109	12:00		128	1.51	
110	13:00		128	1.51	
111	14:00		108	1.22	
112	15:00		101	1.12	
113	16:00		103	1.15	
114	17:00		104	1.17	
115	18:00		84	0.88	
116	19:00		80	0.82	Stop work
117	20:00		192	2.43	
118	21:00		376	5.07	
119	22:00		491	6.73	
120	23:00		504	6.91	
121	00:00	02/10/88	540	7.43	
122	01:00	Wednesday	635	8.79	
123	02:00		611	8.45	
124	03:00		668	9.27	
125	04:00		721	10.03	
126	05:00		717	9.97	
127	06:00		772	10.76	
128	07:00		775	10.81	
129	08:00		757	10.55	
130	09:00		739	10.29	Start work
131	10:00		638	8.84	
132	11:00		409	5.55	
133	12:00		200	2.54	
134	13:00		121	1.41	
135	14:00		100	1.11	
136	15:00		51	0.40	
137	16:00		38	0.22	
138	17:00		36	0.19	Stop work
139	18:00		50	0.39	Basement Closed
140	19:00		133	1.58	Fans off
141	20:00		253	3.31	
142	21:00		367	4.94	
143	22:00		462	6.31	
144	23:00		512	7.03	
145	00:00	02/11/88	610	8.44	
146	01:00	Thursday	664	9.21	

DW 12

147	02:00		714	9.93	
148	03:00		754	10.50	
149	04:00		676	9.38	
150	05:00		668	9.27	
151	06:00		611	8.45	
152	07:00		532	7.31	
153	08:00		442	6.02	
154	09:00		519	7.13	
155	10:00		532	7.31	
156	11:00		567	7.82	
157	12:00		566	7.80	
158	13:00		602	8.32	
159	14:00		569	7.85	
160	15:00		630	8.72	
161	16:00		750	10.45	
162	17:00		824	11.51	
163	18:00		830	11.60	
164	19:00		897	12.56	
165	20:00		934	13.09	
166	21:00		957	13.42	
167	22:00		962	13.49	
168	23:00		1047	14.71	
169	00:00	02/12/88	1041	14.63	
170	01:00	Friday	1091	15.35	
171	02:00		1041	14.63	Pre-mit level ck.
172	03:00		1022	14.36	For 145-176
173	04:00		1129	15.89	Minimum= 6.02 pCi/l
174	05:00		1138	16.02	Maximum= 16.75
175	06:00		1189	16.75	Average= 11.15
176	07:00		1060	14.90	Std.Dev.= 3.16
177	08:00		1094	15.39	Fans on 7:32am
178	09:00		700	9.73	
179	10:00		374	5.04	
180	11:00		218	2.80	
181	12:00		145	1.75	
182	13:00		119	1.38	
183	14:00		124	1.45	
184	15:00		109	1.24	
185	16:00		124	1.45	
186	17:00		109	1.24	
187	18:00		121	1.41	
188	19:00		209	2.67	
189	20:00		182	2.29	
190	21:00		215	2.76	
191	22:00		251	3.28	
192	23:00		155	1.90	
193	00:00	02/13/88	126	1.48	
194	01:00	Saturday	114	1.31	
195	02:00		81	0.84	
196	03:00		113	1.29	
197	04:00		89	0.95	

DW 12

198	05:00		92	0.99
199	06:00		103	1.15
200	07:00		82	0.85
201	08:00		92	0.99
202	09:00		56	0.48
203	10:00		81	0.84
204	11:00		95	1.04
205	12:00		84	0.88
206	13:00		97	1.06
207	14:00		108	1.22
208	15:00		80	0.82
209	16:00		86	0.91
210	17:00		87	0.92
211	18:00		99	1.09
212	19:00		80	0.82
213	20:00		98	1.08
214	21:00		91	0.98
215	22:00		107	1.21
216	23:00		76	0.76
217	00:00	02/14/88	92	0.99
218	01:00	Sunday	106	1.19
219	02:00		111	1.27
220	03:00		84	0.88
221	04:00		116	1.34
222	05:00		110	1.25
223	06:00		109	1.24
224	07:00		111	1.27
225	08:00		88	0.94
226	09:00		74	0.73
227	10:00		68	0.65
228	11:00		75	0.75
229	12:00		72	0.71
230	13:00		72	0.71
231	14:00		63	0.58
232	15:00		64	0.59
233	16:00		80	0.82
234	17:00		59	0.52
235	18:00		60	0.53
236	19:00		79	0.81
237	20:00		67	0.63
238	21:00		98	1.08
239	22:00		71	0.69
240	23:00		48	0.36
241	00:00	02/15/88	71	0.69
242	01:00	Monday	59	0.52
243	02:00		67	0.63
244	03:00		65	0.61
245	04:00		63	0.58
246	05:00		51	0.40
247	06:00		62	0.56
248	07:00		90	0.96

DW 12

249	08:00		100	1.11
250	09:00		103	1.15
251	10:00		93	1.01
252	11:00		85	0.89
253	12:00		81	0.84
254	13:00		95	1.04
255	14:00		83	0.86
256	15:00		57	0.49
257	16:00		86	0.91
258	17:00		80	0.82
259	18:00		103	1.15
260	19:00		82	0.85
261	20:00		67	0.63
262	21:00		72	0.71
263	22:00		92	0.99
264	23:00		79	0.81
265	00:00	02/16/88	67	0.63
266	01:00	Tuesday	81	0.84
267	02:00		105	1.18
268	03:00		87	0.92
269	04:00		107	1.21
270	05:00		89	0.95
271	06:00		85	0.89
272	07:00		79	0.81
273	08:00		91	0.98
274	09:00		116	1.34
275	10:00		95	1.04
276	11:00		91	0.98
277	12:00		77	0.78
278	13:00		56	0.48
279	14:00		70	0.68
280	15:00		63	0.58
281	16:00		64	0.59
282	17:00		48	0.36
283	18:00		60	0.53
284	19:00		61	0.55
285	20:00		67	0.63
286	21:00		71	0.69
287	22:00		85	0.89
288	23:00		91	0.98
289	00:00	02/17/88	87	0.92
290	01:00	Wednesday	82	0.85
291	02:00		90	0.96
292	03:00		114	1.31
293	04:00		101	1.12
294	05:00		113	1.29
295	06:00		120	1.40
296	07:00		136	1.63
297	08:00		136	1.63
298	09:00		87	0.92
299	10:00		94	1.02

DW 12

300	11:00		79	0.81			
301	12:00		65	0.61			
302	13:00		57	0.49			
303	14:00		64	0.59			
304	15:00		51	0.40			
305	16:00		71	0.69			
306	17:00		74	0.73			
307	18:00		75	0.75			
308	19:00		80	0.82			
309	20:00		86	0.91			
310	21:00		84	0.88			
311	22:00		85	0.89			
312	23:00		94	1.02			
313	00:00	02/18/88	85	0.89			
314	01:00	Thursday	94	1.02			
315	02:00		97	1.06			
316	03:00		106	1.19			
317	04:00		130	1.54			
318	05:00		132	1.57			
319	06:00		114	1.31			
320	07:00		99	1.09			
321	08:00		124	1.45			
322	09:00		112	1.28			
323	10:00		96	1.05			
324	11:00		96	1.05			
325	12:00		92	0.99			
326	13:00		80	0.82			
327	14:00		74	0.73			
328	15:00		63	0.58			
329	16:00		87	0.92			
330	17:00		98	1.08			
331	18:00		61	0.55			
332	19:00		68	0.65			
333	20:00		99	1.09			
334	21:00		90	0.96			
335	22:00		152	1.86			
336	23:00		134	1.60			
337	00:00	02/19/88	131	1.55			
338	01:00	Friday	89	0.95			
339	02:00		104	1.17			
340	03:00		85	0.89			
341	04:00		92	0.99			
342	05:00		71	0.69			
343	06:00		66	0.62	Post-mit level		
344	07:00		62	0.56	For 182-348		
345	08:00		82	0.85	Minimum-	0.36	pCi/l
346	09:00		80	0.82	Maximum-	3.28	
347	10:00		92	0.99	Average-	0.98	
348	11:00		79	0.81	Std.Dev.-	0.41	

House DW 14	Continuous Radon Monitor Results				
Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	02/19/88	0	0.00	
2	01:00	Friday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	Start Pre-Mit
14	13:00		672	9.33	Monitoring AB5 #4
15	14:00		898	12.57	Fans turned off
16	15:00		1104	15.53	
17	16:00		1287	18.16	
18	17:00		1544	21.86	
19	18:00		1623	22.99	
20	19:00		1797	25.49	
21	20:00		1803	25.58	
22	21:00		1868	26.51	
23	22:00		2039	28.97	
24	23:00		2118	30.10	
25	00:00	02/20/88	2231	31.73	
26	01:00	Saturday	2362	33.61	
27	02:00		2793	39.80	
28	03:00		2791	39.77	
29	04:00		3021	43.08	
30	05:00		3141	44.80	
31	06:00		3393	48.42	
32	07:00		3126	44.59	
33	08:00		2983	42.53	
34	09:00		2933	41.81	
35	10:00		2952	42.09	
36	11:00		3005	42.85	
37	12:00		3007	42.88	
38	13:00		3139	44.77	
39	14:00		3098	44.18	
40	15:00		1649	23.36	
41	16:00		603	8.34	Homeowner
42	17:00		230	2.98	Venting
43	18:00		295	3.91	Basement
44	19:00		874	12.23	

DW 14

45	20:00		1453	20.55		
46	21:00		2044	29.04		
47	22:00		2416	34.38		
48	23:00		2797	39.86		
49	00:00	02/21/88	3335	47.59		
50	01:00	Sunday	3707	52.93		
51	02:00		4015	57.36		
52	03:00		4361	62.33		
53	04:00		4406	62.98		
54	05:00		4569	65.32		
55	06:00		4512	64.50		
56	07:00		4396	62.83		
57	08:00		4041	57.73		
58	09:00		4006	57.23		
59	10:00		3706	52.92		
60	11:00		3841	54.86		
61	12:00		3954	56.48		
62	13:00		3953	56.47		
63	14:00		3918	55.96		
64	15:00		3880	55.42		
65	16:00		3933	56.18		
66	17:00		3914	55.91		
67	18:00		3943	56.32		
68	19:00		3954	56.48		
69	20:00		4055	57.93		
70	21:00		4075	58.22		
71	22:00		4199	60.00		
72	23:00		3975	56.78		
73	00:00	02/22/88	4030	57.57		
74	01:00	Monday	4228	60.42		
75	02:00		4203	60.06		
76	03:00		4140	59.15		
77	04:00		4267	60.98		
78	05:00		4078	58.26		
79	06:00		3963	56.61		
80	07:00		3692	52.72		
81	08:00		3176	45.30	Pre-Mit level	
82	09:00		2927	41.73	For 48-86	
83	10:00		2583	36.78	Minimum-	31.61 pCi/l
84	11:00		2562	36.48	Maximum-	65.32
85	12:00		2344	33.35	Average-	54.14
86	13:00		2223	31.61	Std.Dev.-	8.49
87	14:00		2088	29.67	Fans on at	
88	15:00		1991	28.28	2:24pm	
89	16:00		1537	21.75		
90	17:00		1110	15.62		
91	18:00		736	10.25		
92	19:00		666	9.24		
93	20:00		561	7.73		
94	21:00		536	7.37		
95	22:00		462	6.31		

DW 14

96	23:00		508	6.97
97	00:00	02/23/88	428	5.82
98	01:00	Tuesday	367	4.94
99	02:00		360	4.84
100	03:00		333	4.46
101	04:00		307	4.08
102	05:00		566	7.80
103	06:00		876	12.26
104	07:00		995	13.97
105	08:00		1117	15.72
106	09:00		1026	14.41
107	10:00		1029	14.46
108	11:00		980	13.75
109	12:00		979	13.74
110	13:00		976	13.69
111	14:00		998	14.01
112	15:00		980	13.75
113	16:00		949	13.31
114	17:00		981	13.77
115	18:00		954	13.38
116	19:00		973	13.65
117	20:00		977	13.71
118	21:00		1050	14.76
119	22:00		1116	15.71
120	23:00		1143	16.09
121	00:00	02/24/88	1206	17.00
122	01:00	Wednesday	1159	16.32
123	02:00		1212	17.09
124	03:00		1282	18.09
125	04:00		1288	18.18
126	05:00		1352	19.10
127	06:00		1311	18.51
128	07:00		1413	19.97
129	08:00		1250	17.63
130	09:00		1115	15.69
131	10:00		1021	14.34
132	11:00		1048	14.73
133	12:00		1120	15.76
134	13:00		1269	17.90
135	14:00		1393	19.69
136	15:00		1401	19.80
137	16:00		1387	19.60
138	17:00		1317	18.59
139	18:00		1211	17.07
140	19:00		1185	16.70
141	20:00		1200	16.91
142	21:00		1300	18.35
143	22:00		1178	16.60
144	23:00		1215	17.13
145	00:00	02/25/88	1333	18.82
146	01:00	Thursday	1455	20.58

DW 14

147	02:00		1503	21.27		
148	03:00		1601	22.67		
149	04:00		1639	23.22		
150	05:00		1588	22.49		
151	06:00		1625	23.02		
152	07:00		1615	22.88		
153	08:00		1486	21.02		
154	09:00		1284	18.12		
155	10:00		1109	15.61		
156	11:00		1102	15.50		
157	12:00		1151	16.21		
158	13:00		1317	18.59		
159	14:00		1339	18.91		
160	15:00		1359	19.20		
161	16:00		1447	20.46		
162	17:00		1423	20.12		
163	18:00		1431	20.23		
164	19:00		1352	19.10		
165	20:00		1283	18.11		
166	21:00		1257	17.73		
167	22:00		1230	17.34		
168	23:00		1169	16.47		
169	00:00	02/26/88	1391	19.66		
170	01:00	Friday	1475	20.86		
171	02:00		1499	21.21	Two SSS level	
172	03:00		1568	22.20	For 92-176	
173	04:00		1572	22.26	Minimum=	4.08 pCi/l
174	05:00		1701	24.11	Maximum=	24.11
175	06:00		1652	23.41	Average=	16.34
176	07:00		1610	22.80	Std.Dev.=	4.81
177	08:00		1484	20.99	Install	
178	09:00		1366	19.30	Wall Suction	
179	10:00		1334	18.84		
180	11:00		1381	19.51		
181	12:00		1101	15.49		
182	13:00		655	9.08		
183	14:00		375	5.06		
184	15:00		283	3.74		
185	16:00		215	2.76		
186	17:00		268	3.52		
187	18:00		357	4.80		
188	19:00		327	4.37		
189	20:00		369	4.97		
190	21:00		366	4.93		
191	22:00		339	4.54		
192	23:00		413	5.61		
193	00:00	02/27/88	390	5.27		
194	01:00	Saturday	403	5.46		
195	02:00		353	4.74		
196	03:00		353	4.74		
197	04:00		382	5.16		

DW 14

198	05:00		348	4.67
199	06:00		340	4.56
200	07:00		324	4.33
201	08:00		357	4.80
202	09:00		332	4.44
203	10:00		355	4.77
204	11:00		404	5.48
205	12:00		371	5.00
206	13:00		432	5.88
207	14:00		534	7.34
208	15:00		440	5.99
209	16:00		481	6.58
210	17:00		494	6.77
211	18:00		543	7.47
212	19:00		551	7.59
213	20:00		495	6.78
214	21:00		517	7.10
215	22:00		514	7.06
216	23:00		595	8.22
217	00:00	02/28/88	615	8.51
218	01:00	Sunday	683	9.48
219	02:00		720	10.02
220	03:00		773	10.78
221	04:00		808	11.28
222	05:00		792	11.05
223	06:00		789	11.01
224	07:00		868	12.14
225	08:00		826	11.54
226	09:00		806	11.25
227	10:00		801	11.18
228	11:00		792	11.05
229	12:00		711	9.89
230	13:00		679	9.43
231	14:00		562	7.75
232	15:00		633	8.77
233	16:00		569	7.85
234	17:00		484	6.63
235	18:00		470	6.42
236	19:00		406	5.50
237	20:00		453	6.18
238	21:00		515	7.07
239	22:00		591	8.16
240	23:00		690	9.59
241	00:00	02/29/88	716	9.96
242	01:00	Monday	856	11.97
243	02:00		844	11.80
244	03:00		856	11.97
245	04:00		867	12.13
246	05:00		895	12.53
247	06:00		875	12.24
248	07:00		768	10.71

DW 14

249	08:00		671	9.31		
250	09:00		651	9.02		
251	10:00		719	10.00		
252	11:00		724	10.07		
253	12:00		678	9.41		
254	13:00		607	8.39		
255	14:00		623	8.62		
256	15:00		696	9.67		
257	16:00		650	9.01		
258	17:00		557	7.67		
259	18:00		577	7.96		
260	19:00		514	7.06		
261	20:00		491	6.73		
262	21:00		533	7.33		
263	22:00		545	7.50		
264	23:00		579	7.99		
265	00:00	03/01/88	636	8.81		
266	01:00	Tuesday	738	10.27		
267	02:00		852	11.91		
268	03:00		827	11.55		
269	04:00		795	11.09		
270	05:00		892	12.49		
271	06:00		900	12.60		
272	07:00		888	12.43		
273	08:00		818	11.42		
274	09:00		745	10.38		
275	10:00		687	9.54		
276	11:00		638	8.84		
277	12:00		547	7.53		
278	13:00		465	6.35		
279	14:00		474	6.48		
280	15:00		460	6.28		
281	16:00		457	6.24		
282	17:00		434	5.91		
283	18:00		398	5.39		
284	19:00		412	5.59		
285	20:00		510	7.00		
286	21:00		589	8.13		
287	22:00		613	8.48		
288	23:00		740	10.30		
289	00:00	03/02/88	778	10.85		
290	01:00	Wednesday	825	11.52		
291	02:00		765	10.66		
292	03:00		838	11.71	SSS+Wall level	
293	04:00		785	10.95	For 182-297	
294	05:00		858	12.00	Minimum-	2.76 pCi/l
295	06:00		780	10.88	Maximum-	12.60
296	07:00		762	10.62	Average-	8.27
297	08:00		695	9.66	Std.Dev.-	2.58
298	09:00		718	9.99		
299	10:00		502	6.88	Capping	

DW 14

300	11:00		414	5.62	c/s wall
301	12:00		366	4.93	top
302	13:00		333	4.46	Sealed poly
303	14:00		290	3.84	1:20pm
304	15:00		241	3.13	
305	16:00		173	2.16	
306	17:00		158	1.94	
307	18:00		168	2.09	
308	19:00		175	2.19	
309	20:00		204	2.60	
310	21:00		262	3.44	
311	22:00		303	4.02	
312	23:00		305	4.05	
313	00:00	03/03/88	377	5.09	
314	01:00	Thursday	392	5.30	
315	02:00		422	5.73	
316	03:00		423	5.75	
317	04:00		418	5.68	
318	05:00		428	5.82	
319	06:00		388	5.25	
320	07:00		407	5.52	
321	08:00		371	5.00	
322	09:00		391	5.29	
323	10:00		373	5.03	
324	11:00		313	4.17	
325	12:00		285	3.77	
326	13:00		233	3.02	
327	14:00		235	3.05	
328	15:00		189	2.39	
329	16:00		210	2.69	
330	17:00		158	1.94	
331	18:00		148	1.80	
332	19:00		174	2.17	
333	20:00		209	2.67	
334	21:00		191	2.42	
335	22:00		162	2.00	
336	23:00		173	2.16	
337	00:00	03/04/88	184	2.31	
338	01:00	Friday	270	3.55	
339	02:00		317	4.23	
340	03:00		288	3.81	
341	04:00		344	4.61	
342	05:00		359	4.83	SSS+Wall+seal c/s level
343	06:00		375	5.06	For 305-347
344	07:00		376	5.07	Minimum= 1.80 pCi/l
345	08:00		442	6.02	Maximum= 7.16
346	09:00		455	6.21	Average= 3.93
347	10:00		521	7.16	Std.Dev.= 1.49
					Stop Post-Mit Monitoring

House DW 27 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
-----	-----	-----	-----	-----	-----
1	00:00	01/22/88	0	0.00	
2	01:00	Friday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		0	0.00	
17	16:00		1836	27.43	AB5 #1
18	17:00		2038	30.49	
19	18:00		1923	28.75	
20	19:00		2133	31.93	
21	20:00		2180	32.64	
22	21:00		2255	33.78	
23	22:00		2196	32.88	
24	23:00		2129	31.87	
25	00:00	01/23/88	2127	31.84	
26	01:00	Saturday	2198	32.91	
27	02:00		2337	35.02	
28	03:00		2441	36.60	
29	04:00		2397	35.93	
30	05:00		2331	34.93	
31	06:00		2257	33.81	
32	07:00		2459	36.87	
33	08:00		2373	35.57	
34	09:00		2396	35.91	
35	10:00		2501	37.50	
36	11:00		2453	36.78	
37	12:00		2439	36.57	
38	13:00		2331	34.93	
39	14:00		2217	33.20	
40	15:00		2071	30.99	
41	16:00		2052	30.70	
42	17:00		2142	32.07	
43	18:00		1987	29.72	
44	19:00		1643	24.50	

DW 27

45	20:00		1628	24.28
46	21:00		1608	23.97
47	22:00		1910	28.55
48	23:00		1925	28.78
49	00:00	01/24/88	2058	30.79
50	01:00	Sunday	2196	32.88
51	02:00		2214	33.16
52	03:00		2288	34.28
53	04:00		2321	34.78
54	05:00		2352	35.25
55	06:00		2381	35.69
56	07:00		2360	35.37
57	08:00		2343	35.11
58	09:00		2354	35.28
59	10:00		2243	33.60
60	11:00		2242	33.58
61	12:00		2198	32.91
62	13:00		2150	32.19
63	14:00		2112	31.61
64	15:00		1950	29.16
65	16:00		2097	31.38
66	17:00		2125	31.81
67	18:00		2035	30.44
68	19:00		2187	32.75
69	20:00		2154	32.25
70	21:00		2116	31.67
71	22:00		2158	32.31
72	23:00		2133	31.93
73	00:00	01/25/88	2151	32.20
74	01:00	Monday	2172	32.52
75	02:00		2206	33.04
76	03:00		2316	34.70
77	04:00		2352	35.25
78	05:00		2395	35.90
79	06:00		2320	34.76
80	07:00		2403	36.02
81	08:00		2447	36.69
82	09:00		2375	35.60
83	10:00		2315	34.69
84	11:00		2611	39.17
85	12:00		2632	39.49
86	13:00		2485	37.26
87	14:00		2431	36.44
88	15:00		2399	35.96
89	16:00		2316	34.70
90	17:00		2098	31.40
91	18:00		1972	29.49
92	19:00		1674	24.97
93	20:00		1603	23.90
94	21:00		1628	24.28
95	22:00		1556	23.19

DW 27

96	23:00		1865	27.87		
97	00:00	01/26/88	1994	29.82		
98	01:00	Tuesday	2096	31.37		
99	02:00		2153	32.23		
100	03:00		2133	31.93		
101	04:00		2238	33.52		
102	05:00		2236	33.49		
103	06:00		2214	33.16		
104	07:00		2255	33.78		
105	08:00		2383	35.72		
106	09:00		2271	34.02		
107	10:00		2112	31.61		
108	11:00		1360	20.22		
109	12:00		1032	15.25		
110	13:00		1009	14.90		
111	14:00		1069	15.81		
112	15:00		1126	16.67		
113	16:00		1003	14.81		
114	17:00		681	9.93		
115	18:00		524	7.55		
116	19:00		505	7.26		
117	20:00		755	11.05		
118	21:00		1047	15.47		
119	22:00		1369	20.35		
120	23:00		1541	22.96		
121	00:00	01/27/88	1697	25.32		
122	01:00	Wednesday	1735	25.90		
123	02:00		1854	27.70		
124	03:00		1964	29.37		
125	04:00		2109	31.57		
126	05:00		2212	33.13		
127	06:00		2300	34.46	Pre-mit level	
128	07:00		2257	33.81	For 19-132	
129	08:00		2389	35.81	Minimum-	7.26 pCi/l
130	09:00		2306	34.55	Maximum-	39.49
131	10:00		2241	33.57	Average-	30.50
132	11:00		1737	25.93	Std.Dev.-	6.72
133	12:00		1275	18.93		
134	13:00		873	12.84		
135	14:00		606	8.79		
136	15:00		553	7.99		
137	16:00		578	8.37		
138	17:00		756	11.07		
139	18:00		765	11.20	SubPoly Fan on 6pm	
140	19:00		733	10.72		
141	20:00		606	8.79		
142	21:00		610	8.85		
143	22:00		664	9.67		
144	23:00		723	10.57		
145	00:00	01/28/88	819	12.02		
146	01:00	Thursday	875	12.87		

DW 27

147	02:00		943	13.90
148	03:00		885	13.02
149	04:00		943	13.90
150	05:00		969	14.29
151	06:00		1045	15.44
152	07:00		994	14.67
153	08:00		1015	14.99
154	09:00		908	13.37
155	10:00		908	13.37
156	11:00		913	13.44
157	12:00		899	13.23
158	13:00		889	13.08
159	14:00		828	12.16
160	15:00		853	12.54
161	16:00		784	11.49
162	17:00		748	10.94
163	18:00		662	9.64
164	19:00		385	5.44
165	20:00		300	4.16
166	21:00		247	3.35
167	22:00		317	4.41
168	23:00		390	5.52
169	00:00	01/29/88	463	6.63
170	01:00	Friday	519	7.47
171	02:00		553	7.99
172	03:00		661	9.63
173	04:00		718	10.49
174	05:00		762	11.16
175	06:00		725	10.60
176	07:00		773	11.32
177	08:00		817	11.99
178	09:00		857	12.60
179	10:00		701	10.23
180	11:00		708	10.34
181	12:00		735	10.75
182	13:00		692	10.10
183	14:00		629	9.14
184	15:00		596	8.64
185	16:00		564	8.16
186	17:00		547	7.90
187	18:00		579	8.38
188	19:00		510	7.34
189	20:00		433	6.17
190	21:00		473	6.78
191	22:00		460	6.58
192	23:00		547	7.90
193	00:00	01/30/88	567	8.20
194	01:00	Saturday	640	9.31
195	02:00		664	9.67
196	03:00		628	9.13
197	04:00		665	9.69

DW 27

198	05:00		657	9.57
199	06:00		746	10.91
200	07:00		745	10.90
201	08:00		783	11.47
202	09:00		737	10.78
203	10:00		781	11.44
204	11:00		726	10.61
205	12:00		734	10.73
206	13:00		671	9.78
207	14:00		697	10.17
208	15:00		607	8.81
209	16:00		580	8.40
210	17:00		540	7.79
211	18:00		560	8.10
212	19:00		476	6.82
213	20:00		405	5.75
214	21:00		400	5.67
215	22:00		421	5.99
216	23:00		446	6.37
217	00:00	01/31/88	555	8.02
218	01:00	Sunday	565	8.17
219	02:00		545	7.87
220	03:00		542	7.82
221	04:00		482	6.91
222	05:00		522	7.52
223	06:00		513	7.38
224	07:00		547	7.90
225	08:00		532	7.67
226	09:00		509	7.32
227	10:00		524	7.55
228	11:00		505	7.26
229	12:00		560	8.10
230	13:00		550	7.94
231	14:00		582	8.43
232	15:00		587	8.50
233	16:00		491	7.05
234	17:00		442	6.31
235	18:00		478	6.85
236	19:00		395	5.60
237	20:00		439	6.26
238	21:00		464	6.64
239	22:00		463	6.63
240	23:00		485	6.96
241	00:00	02/01/88	476	6.82
242	01:00	Monday	429	6.11
243	02:00		342	4.79
244	03:00		344	4.82
245	04:00		343	4.81
246	05:00		394	5.58
247	06:00		381	5.38
248	07:00		433	6.17

DW 27

249	08:00		377	5.32
250	09:00		433	6.17
251	10:00		361	5.08
252	11:00		323	4.50
253	12:00		332	4.64
254	13:00		353	4.96
255	14:00		331	4.63
256	15:00		335	4.69
257	16:00		331	4.63
258	17:00		349	4.90
259	18:00		424	6.04
260	19:00		454	6.49
261	20:00		511	7.35
262	21:00		494	7.10
263	22:00		496	7.13
264	23:00		443	6.32
265	00:00	02/02/88	397	5.63
266	01:00	Tuesday	369	5.20
267	02:00		375	5.29
268	03:00		269	3.69
269	04:00		275	3.78
270	05:00		255	3.47
271	06:00		233	3.14
272	07:00		213	2.84
273	08:00		300	4.16
274	09:00		311	4.32
275	10:00		298	4.13
276	11:00		300	4.16
277	12:00		356	5.00
278	13:00		461	6.60
279	14:00		428	6.10
280	15:00		555	8.02
281	16:00		568	8.22
282	17:00		603	8.75
283	18:00		564	8.16
284	19:00		612	8.88
285	20:00		591	8.57
286	21:00		666	9.70
287	22:00		605	8.78
288	23:00		638	9.28
289	00:00	02/03/88	617	8.96
290	01:00	Wednesday	564	8.16
291	02:00		608	8.82
292	03:00		574	8.31
293	04:00		605	8.78
294	05:00		642	9.34
295	06:00		691	10.08
296	07:00		713	10.41
297	08:00		715	10.44
298	09:00		697	10.17
299	10:00		642	9.34

DW 27

300	11:00		686	10.00	
301	12:00		686	10.00	
302	13:00		707	10.32	
303	14:00		735	10.75	
304	15:00		669	9.75	
305	16:00		680	9.91	
306	17:00		663	9.66	
307	18:00		606	8.79	One SPS level
308	19:00		632	9.19	For 146-312
309	20:00		638	9.28	Minimum- 2.84 pCi/l
310	21:00		626	9.10	Maximum- 15.44
311	22:00		657	9.57	Average- 8.25
312	23:00		580	8.40	Std.Dev.- 2.70
313	00:00	02/04/88		0.00	Battery dead on AB5
314	01:00	Thursday		0.00	
315	02:00			0.00	
316	03:00			0.00	
317	04:00			0.00	
318	05:00			0.00	
319	06:00			0.00	
320	07:00			0.00	
321	08:00			0.00	
322	09:00			0.00	
323	10:00			0.00	
324	11:00			0.00	
325	12:00			0.00	
326	13:00			0.00	
327	14:00			0.00	
328	15:00			0.00	
329	16:00			0.00	
330	17:00			0.00	
331	18:00			0.00	
332	19:00			0.00	
333	20:00			0.00	
334	21:00			0.00	
335	22:00			0.00	
336	23:00			0.00	
337	00:00	02/05/88		0.00	
338	01:00	Friday		0.00	
339	02:00			0.00	
340	03:00			0.00	
341	04:00			0.00	
342	05:00			0.00	
343	06:00			0.00	
344	07:00			0.00	
345	08:00			0.00	
346	09:00			0.00	
347	10:00			0.00	
348	11:00			0.00	
349	12:00		772	11.31	Restart AB5
350	13:00		680	9.91	w/charger

DW 27

351	14:00		660	9.61
352	15:00		691	10.08
353	16:00		656	9.55
354	17:00		668	9.73
355	18:00		662	9.64
356	19:00		737	10.78
357	20:00		691	10.08
358	21:00		646	9.40
359	22:00		601	8.72
360	23:00		634	9.22
361	00:00	02/06/88	714	10.43
362	01:00	Saturday	730	10.67
363	02:00		795	11.66
364	03:00		893	13.14
365	04:00		863	12.69
366	05:00		838	12.31
367	06:00		906	13.34
368	07:00		910	13.40
369	08:00		924	13.61
370	09:00		908	13.37
371	10:00		922	13.58
372	11:00		949	13.99
373	12:00		886	13.04
374	13:00		1002	14.79
375	14:00		943	13.90
376	15:00		852	12.52
377	16:00		824	12.10
378	17:00		840	12.34
379	18:00		833	12.23
380	19:00		768	11.25
381	20:00		860	12.64
382	21:00		912	13.43
383	22:00		914	13.46
384	23:00		880	12.94
385	00:00	02/07/88	912	13.43
386	01:00	Sunday	855	12.57
387	02:00		927	13.66
388	03:00		949	13.99
389	04:00		996	14.70
390	05:00		1035	15.29
391	06:00		1032	15.25
392	07:00		1009	14.90
393	08:00		947	13.96
394	09:00		1078	15.94
395	10:00		989	14.60
396	11:00		986	14.55
397	12:00		985	14.54
398	13:00		1012	14.94
399	14:00		911	13.41
400	15:00		885	13.02
401	16:00		903	13.29

DW 27

402	17:00		892	13.13
403	18:00		809	11.87
404	19:00		769	11.26
405	20:00		778	11.40
406	21:00		824	12.10
407	22:00		782	11.46
408	23:00		759	11.11
409	00:00	02/08/88	752	11.00
410	01:00	Monday	729	10.66
411	02:00		780	11.43
412	03:00		771	11.29
413	04:00		815	11.96
414	05:00		801	11.75
415	06:00		825	12.11
416	07:00		819	12.02
417	08:00		847	12.44
418	09:00		798	11.70
419	10:00		848	12.46
420	11:00		832	12.22
421	12:00		827	12.14
422	13:00		826	12.13
423	14:00		837	12.29
424	15:00		816	11.97
425	16:00		807	11.84
426	17:00		851	12.50
427	18:00		775	11.35
428	19:00		743	10.87
429	20:00		747	10.93
430	21:00		759	11.11
431	22:00		775	11.35
432	23:00		767	11.23
433	00:00	02/09/88	703	10.26
434	01:00	Tuesday	722	10.55
435	02:00		789	11.57
436	03:00		828	12.16
437	04:00		829	12.17
438	05:00		900	13.25
439	06:00		960	14.16
440	07:00		969	14.29
441	08:00		827	12.14
442	09:00		849	12.47
443	10:00		847	12.44
444	11:00		793	11.63
445	12:00		787	11.54
446	13:00		837	12.29
447	14:00		831	12.20
448	15:00		818	12.00
449	16:00		791	11.60
450	17:00		668	9.73
451	18:00		725	10.60
452	19:00		713	10.41

DW 27

453	20:00		735	10.75		
454	21:00		718	10.49		
455	22:00		787	11.54		
456	23:00		795	11.66		
457	00:00	02/10/88	775	11.35		
458	01:00	Wednesday	838	12.31		
459	02:00		812	11.91		
460	03:00		899	13.23		
461	04:00		874	12.85		
462	05:00		916	13.49		
463	06:00		979	14.44		
464	07:00		851	12.50		
465	08:00		887	13.05		
466	09:00		909	13.38		
467	10:00		888	13.07		
468	11:00		921	13.57		
469	12:00		944	13.91		
470	13:00		890	13.10		
471	14:00		847	12.44		
472	15:00		881	12.96		
473	16:00		760	11.13		
474	17:00		703	10.26		
475	18:00		711	10.38		
476	19:00		681	9.93		
477	20:00		691	10.08		
478	21:00		694	10.13		
479	22:00		678	9.88		
480	23:00		717	10.47		
481	00:00	02/11/88	652	9.49		
482	01:00	Thursday	669	9.75		
483	02:00		641	9.32	One SPS level	
484	03:00		659	9.60	For 352-488	
485	04:00		668	9.73	Minimum-	8.72 pCi/l
486	05:00		732	10.70	Maximum-	15.94
487	06:00		746	10.91	Average-	12.06
488	07:00		779	11.41	Std.Dev.-	1.51
489	08:00		744	10.88	Start Phase B Mit	
490	09:00		717	10.47	2nd Suction Pt	
491	10:00		679	9.90	Seal Poly edges	
492	11:00		591	8.57		
493	12:00		563	8.14		
494	13:00		547	7.90		
495	14:00		476	6.82		
496	15:00		340	4.76		
497	16:00		277	3.81		
498	17:00		260	3.55		
499	18:00		314	4.37		
500	19:00		387	5.47		
501	20:00		449	6.41		
502	21:00		460	6.58		
503	22:00		509	7.32		

DW 27

504	23:00		503	7.23
505	00:00	02/12/88	554	8.00
506	01:00	Friday	623	9.05
507	02:00		683	9.96
508	03:00		759	11.11
509	04:00		790	11.58
510	05:00		814	11.94
511	06:00		817	11.99
512	07:00		762	11.16
513	08:00		833	12.23
514	09:00		973	14.35
515	10:00		969	14.29
516	11:00		997	14.72
517	12:00		1007	14.87
518	13:00		928	13.67
519	14:00		902	13.28
520	15:00		906	13.34
521	16:00		910	13.40
522	17:00		763	11.17
523	18:00		839	12.32
524	19:00		864	12.70
525	20:00		768	11.25
526	21:00		747	10.93
527	22:00		695	10.14
528	23:00		720	10.52
529	00:00	02/13/88	743	10.87
530	01:00	Saturday	869	12.78
531	02:00		922	13.58
532	03:00		886	13.04
533	04:00		927	13.66
534	05:00		983	14.50
535	06:00		999	14.75
536	07:00		1022	15.10
537	08:00		986	14.55
538	09:00		1032	15.25
539	10:00		949	13.99
540	11:00		928	13.67
541	12:00		937	13.81
542	13:00		903	13.29
543	14:00		920	13.55
544	15:00		908	13.37
545	16:00		856	12.58
546	17:00		967	14.26
547	18:00		930	13.70
548	19:00		933	13.75
549	20:00		845	12.41
550	21:00		847	12.44
551	22:00		959	14.14
552	23:00		948	13.97
553	00:00	02/14/88	1037	15.32
554	01:00	Sunday	924	13.61

DW 27

555	02:00		915	13.47	
556	03:00		979	14.44	
557	04:00		981	14.47	
558	05:00		1021	15.08	
559	06:00		962	14.19	
560	07:00		986	14.55	
561	08:00		1025	15.14	
562	09:00		933	13.75	
563	10:00		829	12.17	
564	11:00		852	12.52	
565	12:00		866	12.73	
566	13:00		822	12.07	
567	14:00		819	12.02	
568	15:00		775	11.35	
569	16:00		744	10.88	
570	17:00		723	10.57	
571	18:00		738	10.79	
572	19:00		673	9.81	
573	20:00		722	10.55	
574	21:00		687	10.02	
575	22:00		626	9.10	
576	23:00		618	8.97	
577	00:00	02/15/88	589	8.54	
578	01:00	Monday	645	9.38	
579	02:00		683	9.96	
580	03:00		675	9.84	
581	04:00		702	10.25	
582	05:00		716	10.46	
583	06:00		745	10.90	
584	07:00		758	11.10	
585	08:00		687	10.02	
586	09:00		711	10.38	
587	10:00		617	8.96	
588	11:00		440	6.28	
589	12:00		363	5.11	2nd Suction pt on
590	13:00		348	4.88	
591	14:00		345	4.84	
592	15:00		376	5.31	Finish Phase B
593	16:00		442	6.31	
594	17:00		401	5.69	
595	18:00		357	5.02	
596	19:00		299	4.14	
597	20:00		291	4.02	
598	21:00		295	4.08	
599	22:00		270	3.70	
600	23:00		249	3.38	
601	00:00	02/16/88	287	3.96	
602	01:00	Tuesday	313	4.35	
603	02:00		279	3.84	
604	03:00		331	4.63	
605	04:00		354	4.97	

DW 27

606	05:00		316	4.40
607	06:00		365	5.14
608	07:00		344	4.82
609	08:00		354	4.97
610	09:00		407	5.78
611	10:00		422	6.00
612	11:00		400	5.67
613	12:00		390	5.52
614	13:00		379	5.35
615	14:00		349	4.90
616	15:00		356	5.00
617	16:00		308	4.28
618	17:00		314	4.37
619	18:00		300	4.16
620	19:00		334	4.67
621	20:00		275	3.78
622	21:00		271	3.72
623	22:00		317	4.41
624	23:00		279	3.84
625	00:00	02/17/88	282	3.88
626	01:00	Wednesday	262	3.58
627	02:00		255	3.47
628	03:00		301	4.17
629	04:00		298	4.13
630	05:00		286	3.94
631	06:00		288	3.97
632	07:00		300	4.16
633	08:00		318	4.43
634	09:00		271	3.72
635	10:00		288	3.97
636	11:00		285	3.93
637	12:00		259	3.54
638	13:00		222	2.97
639	14:00		224	3.00
640	15:00		216	2.88
641	16:00		221	2.96
642	17:00		192	2.52
643	18:00		171	2.20
644	19:00		197	2.60
645	20:00		180	2.34
646	21:00		195	2.57
647	22:00		204	2.70
648	23:00		185	2.41
649	00:00	02/18/88	174	2.25
650	01:00	Thursday	193	2.53
651	02:00		197	2.60
652	03:00		226	3.04
653	04:00		243	3.29
654	05:00		259	3.54
655	06:00		276	3.79
656	07:00		333	4.66

DW 27

```
657   08:00             319   4.44
658   09:00             265   3.63
659   10:00             272   3.73
660   11:00             264   3.61
661   12:00             282   3.88
662   13:00             294   4.07
663   14:00             248   3.37
664   15:00             233   3.14
665   16:00             253   3.44
666   17:00             242   3.28
667   18:00             239   3.23
668   19:00             211   2.81
669   20:00             235   3.17
670   21:00             246   3.34
671   22:00             306   4.25
672   23:00             256   3.49
673   00:00 02/19/88    287   3.96
674   01:00 Friday      282   3.88
675   02:00             274   3.76
676   03:00             220   2.94
677   04:00             198   2.61
678   05:00             234   3.16 2 SPS+seal poly level
679   06:00             224   3.00 For 593-683
680   07:00             254   3.46 Minimum-     2.20 pCi/l
681   08:00             288   3.97 Maximum-     6.31
682   09:00             271   3.72 Average-     3.84
683   10:00             231   3.11 Std.Dev.-    0.89
```

House DW 29 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	02/19/88	0	0.00	
2	01:00	Friday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	Start Pre Mit
14	13:00		0	0.00	Monitor AB5 #1
15	14:00		0	0.00	
16	15:00		568	8.22	
17	16:00		815	11.96	
18	17:00		917	13.50	
19	18:00		964	14.22	
20	19:00		916	13.49	
21	20:00		1046	15.46	
22	21:00		1058	15.64	
23	22:00		1027	15.17	
24	23:00		1128	16.70	
25	00:00	02/20/88	1121	16.60	
26	01:00	Saturday	1225	18.17	
27	02:00		1188	17.61	
28	03:00		1236	18.34	
29	04:00		1202	17.82	
30	05:00		1176	17.43	
31	06:00		1116	16.52	
32	07:00		1131	16.75	
33	08:00		1088	16.10	
34	09:00		1107	16.38	
35	10:00		1134	16.79	
36	11:00		1145	16.96	
37	12:00		995	14.69	
38	13:00		1073	15.87	
39	14:00		987	14.57	
40	15:00		954	14.07	
41	16:00		880	12.94	
42	17:00		885	13.02	
43	18:00		968	14.28	
44	19:00		1037	15.32	

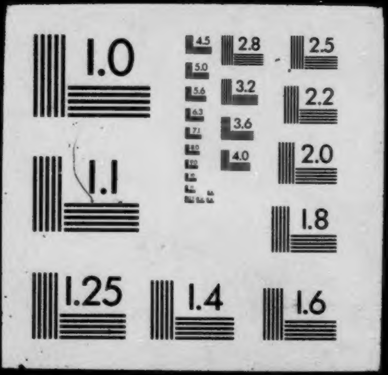
DW 29

45	20:00		1008	14.88		
46	21:00		1105	16.35		
47	22:00		1050	15.52		
48	23:00		1054	15.58		
49	00:00	02/21/88	1090	16.13		
50	01:00	Sunday	1077	15.93		
51	02:00		988	14.58		
52	03:00		1051	15.54		
53	04:00		999	14.75		
54	05:00		1029	15.20		
55	06:00		1029	15.20		
56	07:00		1040	15.37		
57	08:00		1121	16.60		
58	09:00		1105	16.35		
59	10:00		1083	16.02		
60	11:00		1092	16.16		
61	12:00		1095	16.20		
62	13:00		1124	16.64		
63	14:00		1259	18.69		
64	15:00		1275	18.93		
65	16:00		1123	16.63		
66	17:00		1119	16.57		
67	18:00		1067	15.78		
68	19:00		1099	16.26		
69	20:00		1035	15.29		
70	21:00		1045	15.44		
71	22:00		1036	15.31		
72	23:00		1042	15.40		
73	00:00	02/22/88	1114	16.49		
74	01:00	Monday	1251	18.57		
75	02:00		1136	16.82		
76	03:00		1211	17.96		
77	04:00		1233	18.29		
78	05:00		1161	17.20		
79	06:00		1243	18.44	Pre-mit level	
80	07:00		1241	18.41	For 19-84	
81	08:00		1274	18.91	Minimum=	12.94 pCi/l
82	09:00		1204	17.85	Maximum=	18.93
83	10:00		1169	17.32	Average=	16.23
84	11:00		1120	16.58	Std.Dev.=	1.39
85	12:00		1038	15.34	Begin	
86	13:00		767	11.23	Mit Inst	
87	14:00		521	7.50		
88	15:00		314	4.37		
89	16:00		183	2.38		
90	17:00		114	1.34		
91	18:00		119	1.41		
92	19:00		201	2.66		
93	20:00		356	5.00		
94	21:00		485	6.96		
95	22:00		558	8.07		

3 OF 3

PB 90

257791


1.0
4.5
5.0
5.6
6.3
7.1
8.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

DW 29

96	23:00		662	9.64
97	00:00	02/23/88	701	10.23
98	01:00	Tuesday	671	9.78
99	02:00		644	9.37
100	03:00		571	8.26
101	04:00		586	8.49
102	05:00		630	9.16
103	06:00		666	9.70
104	07:00		776	11.37
105	08:00		676	9.85
106	09:00		818	12.00
107	10:00		798	11.70
108	11:00		805	11.81
109	12:00		919	13.54
110	13:00		959	14.14
111	14:00		1016	15.00
112	15:00		1014	14.97
113	16:00		1002	14.79
114	17:00		896	13.19
115	18:00		901	13.26
116	19:00		907	13.35
117	20:00		900	13.25
118	21:00		902	13.28
119	22:00		963	14.20
120	23:00		967	14.26
121	00:00	02/24/88	958	14.13
122	01:00	Wednesday	951	14.02
123	02:00		1098	16.25
124	03:00		1059	15.66
125	04:00		1159	17.17
126	05:00		1158	17.16
127	06:00		1157	17.14
128	07:00		1044	15.43
129	08:00		1157	17.14
130	09:00		1137	16.84
131	10:00		1166	17.28
132	11:00		1010	14.91
133	12:00		975	14.38
134	13:00		832	12.22
135	14:00		763	11.17
136	15:00		718	10.49
137	16:00		813	11.93
138	17:00		861	12.66
139	18:00		953	14.05
140	19:00		982	14.49
141	20:00		967	14.26
142	21:00		985	14.54
143	22:00		1121	16.60
144	23:00		1096	16.22
145	00:00	02/25/88	1091	16.14
146	01:00	Thursday	1077	15.93

DW 29

147	02:00		1153	17.08	
148	03:00		1109	16.41	
149	04:00		1099	16.26	
150	05:00		1166	17.28	
151	06:00		1259	18.69	
152	07:00		1166	17.28	
153	08:00		1187	17.60	
154	09:00		1233	18.29	
155	10:00		1133	16.78	
156	11:00		1154	17.10	
157	12:00		1020	15.07	
158	13:00		794	11.64	
159	14:00		766	11.22	
160	15:00		811	11.90	
161	16:00		780	11.43	
162	17:00		797	11.69	Mit Inst
163	18:00		834	12.25	Complete
164	19:00		869	12.78	Sub-Poly Fan off
165	20:00		948	13.97	Test Seal Only
166	21:00		961	14.17	
167	22:00		939	13.84	
168	23:00		983	14.50	
169	00:00	02/26/88	991	14.63	
170	01:00	Friday	1004	14.82	
171	02:00		990	14.61	
172	03:00		1075	15.90	
173	04:00		1113	16.47	
174	05:00		1208	17.91	
175	06:00		1151	17.05	
176	07:00		1171	17.35	
177	08:00		1123	16.63	
178	09:00		1184	17.55	
179	10:00		1283	19.05	
180	11:00		1261	18.72	
181	12:00		1248	18.52	
182	13:00		1243	18.44	
183	14:00		1310	19.46	
184	15:00		1199	17.78	
185	16:00		1048	15.49	
186	17:00		1069	15.81	
187	18:00		1023	15.11	
188	19:00		1085	16.05	
189	20:00		1097	16.23	
190	21:00		977	14.41	
191	22:00		1084	16.04	
192	23:00		1177	17.44	
193	00:00	02/27/88	1261	18.72	
194	01:00	Saturday	1182	17.52	
195	02:00		1182	17.52	
196	03:00		1205	17.87	
197	04:00		1305	19.38	

DW 29

198	05:00		1277	18.96
199	06:00		1203	17.84
200	07:00		1241	18.41
201	08:00		1287	19.11
202	09:00		1291	19.17
203	10:00		1272	18.88
204	11:00		1251	18.57
205	12:00		1172	17.37
206	13:00		1117	16.54
207	14:00		1028	15.19
208	15:00		980	14.46
209	16:00		877	12.90
210	17:00		886	13.04
211	18:00		804	11.79
212	19:00		838	12.31
213	20:00		846	12.43
214	21:00		873	12.84
215	22:00		893	13.14
216	23:00		853	12.54
217	00:00	02/28/88	808	11.85
218	01:00	Sunday	842	12.37
219	02:00		855	12.57
220	03:00		846	12.43
221	04:00		830	12.19
222	05:00		747	10.93
223	06:00		830	12.19
224	07:00		840	12.34
225	08:00		888	13.07
226	09:00		869	12.78
227	10:00		950	14.00
228	11:00		1071	15.84
229	12:00		1122	16.61
230	13:00		1104	16.34
231	14:00		1079	15.96
232	15:00		998	14.73
233	16:00		920	13.55
234	17:00		872	12.82
235	18:00		820	12.04
236	19:00		754	11.04
237	20:00		906	13.34
238	21:00		841	12.35
239	22:00		907	13.35
240	23:00		953	14.05
241	00:00	02/29/88	985	14.54
242	01:00	Monday	1021	15.08
243	02:00		1099	16.26
244	03:00		1003	14.81
245	04:00		1059	15.66
246	05:00		1116	16.52
247	06:00		1142	16.91
248	07:00		1201	17.81

DW 29

249	08:00		1197	17.75	
250	09:00		1169	17.32	
251	10:00		1157	17.14	
252	11:00		1153	17.08	
253	12:00		1240	18.40	
254	13:00		1220	18.10	
255	14:00		1274	18.91	
256	15:00		1201	17.81	
257	16:00		1174	17.40	
258	17:00		1197	17.75	
259	18:00		1124	16.64	
260	19:00		1120	16.58	
261	20:00		1046	15.46	
262	21:00		1009	14.90	
263	22:00		966	14.25	
264	23:00		1018	15.04	
265	00:00	03/01/88	996	14.70	
266	01:00	Tuesday	1099	16.26	
267	02:00		1078	15.94	
268	03:00		1025	15.14	
269	04:00		1159	17.17	
270	05:00		1207	17.90	Seal c/s level
271	06:00		1158	17.16	For 166-275
272	07:00		1205	17.87	Minimum- 10.93 pCi/l
273	08:00		1123	16.63	Maximum- 19.46
274	09:00		1197	17.75	Average- 15.74
275	10:00		1194	17.70	Std.Dev.- 2.23
276	11:00		1121	16.60	Fan on 11:06 am
277	12:00		1051	15.54	
278	13:00		898	13.22	
279	14:00		868	12.76	
280	15:00		715	10.44	
281	16:00		728	10.64	
282	17:00		635	9.23	
283	18:00		585	8.47	
284	19:00		467	6.69	
285	20:00		382	5.40	
286	21:00		425	6.05	
287	22:00		398	5.64	
288	23:00		417	5.93	
289	00:00	03/02/88	422	6.00	
290	01:00	Wednesday	466	6.67	
291	02:00		498	7.16	
292	03:00		484	6.94	
293	04:00		502	7.22	
294	05:00		536	7.73	
295	06:00		552	7.97	
296	07:00		561	8.11	
297	08:00		527	7.60	
298	09:00		540	7.79	
299	10:00		579	8.38	

DW 29

300	11:00		578	8.37	
301	12:00		567	8.20	
302	13:00		523	7.54	
303	14:00		527	7.60	
304	15:00		495	7.11	Making Dp
305	16:00		465	6.66	meas 4:16pm
306	17:00		446	6.37	
307	18:00		360	5.07	
308	19:00		337	4.72	
309	20:00		360	5.07	
310	21:00		338	4.73	
311	22:00		276	3.79	
312	23:00		290	4.00	
313	00:00	03/03/88	280	3.85	
314	01:00	Thursday	324	4.52	
315	02:00		298	4.13	
316	03:00		279	3.84	
317	04:00		290	4.00	
318	05:00		315	4.38	
319	06:00		294	4.07	
320	07:00		328	4.58	
321	08:00		354	4.97	
322	09:00		249	3.38	
323	10:00		289	3.99	
324	11:00		275	3.78	
325	12:00		337	4.72	Air Temp 68 oF
326	13:00		343	4.81	
327	14:00		377	5.32	
328	15:00		344	4.82	
329	16:00		311	4.32	
330	17:00		279	3.84	
331	18:00		283	3.90	
332	19:00		266	3.64	
333	20:00		241	3.26	
334	21:00		239	3.23	
335	22:00		242	3.28	
336	23:00		223	2.99	
337	00:00	03/04/88	249	3.38	
338	01:00	Friday	245	3.32	
339	02:00		250	3.40	
340	03:00		246	3.34	
341	04:00		234	3.16	
342	05:00		254	3.46	
343	06:00		293	4.05	
344	07:00		289	3.99	Temp 47oF
345	08:00		369	5.20	Wind Chill 31oF
346	09:00		362	5.10	
347	10:00		409	5.81	
348	11:00		388	5.49	
349	12:00		430	6.13	
350	13:00		390	5.52	

DW 29

351	14:00		401	5.69
352	15:00		412	5.85
353	16:00		462	6.61
354	17:00		419	5.96
355	18:00		447	6.38
356	19:00		433	6.17
357	20:00		409	5.81
358	21:00		379	5.35
359	22:00		403	5.72
360	23:00		416	5.91
361	00:00	03/05/88	425	6.05
362	01:00	Saturday	374	5.28
363	02:00		398	5.64
364	03:00		426	6.07
365	04:00		428	6.10
366	05:00		414	5.88
367	06:00		422	6.00
368	07:00		480	6.88
369	08:00		406	5.76
370	09:00		386	5.46
371	10:00		416	5.91
372	11:00		449	6.41
373	12:00		431	6.14
374	13:00		401	5.69
375	14:00		403	5.72
376	15:00		423	6.02
377	16:00		425	6.05
378	17:00		380	5.37
379	18:00		370	5.22
380	19:00		395	5.60
381	20:00		433	6.17
382	21:00		453	6.47
383	22:00		476	6.82
384	23:00		451	6.44
385	00:00	03/06/88	493	7.08
386	01:00	Sunday	519	7.47
387	02:00		496	7.13
388	03:00		475	6.81
389	04:00		538	7.76
390	05:00		507	7.29
391	06:00		504	7.25
392	07:00		507	7.29
393	08:00		492	7.07
394	09:00		507	7.29
395	10:00		542	7.82
396	11:00		540	7.79
397	12:00		525	7.57
398	13:00		524	7.55
399	14:00		571	8.26
400	15:00		537	7.75
401	16:00		510	7.34

DW 29

402	17:00		500	7.19
403	18:00		421	5.99
404	19:00		461	6.60
405	20:00		436	6.22
406	21:00		450	6.43
407	22:00		415	5.90
408	23:00		459	6.57
409	00:00	03/07/88	465	6.66
410	01:00	Monday	425	6.05
411	02:00		440	6.28
412	03:00		518	7.46
413	04:00		491	7.05
414	05:00		494	7.10
415	06:00		551	7.96
416	07:00		518	7.46
417	08:00		491	7.05
418	09:00		463	6.63
419	10:00		523	7.54
420	11:00		477	6.84
421	12:00		523	7.54
422	13:00		477	6.84
423	14:00		477	6.84
424	15:00		410	5.82
425	16:00		462	6.61
426	17:00		464	6.64
427	18:00		422	6.00
428	19:00		391	5.54
429	20:00		410	5.82
430	21:00		399	5.66
431	22:00		351	4.93
432	23:00		364	5.13
433	00:00	03/08/88	308	4.28
434	01:00	Tuesday	353	4.96
435	02:00		380	5.37
436	03:00		412	5.85
437	04:00		367	5.17
438	05:00		417	5.93
439	06:00		371	5.23
440	07:00		357	5.02
441	08:00		414	5.88
442	09:00		385	5.44
443	10:00		397	5.63
444	11:00		390	5.52
445	12:00		464	6.64
446	13:00		573	8.29
447	14:00		461	6.60
448	15:00		469	6.72
449	16:00		394	5.58
450	17:00		400	5.67
451	18:00		388	5.49
452	19:00		386	5.46

DW 29

453	20:00		387	5.47		
454	21:00		364	5.13		
455	22:00		353	4.96		
456	23:00		305	4.23		
457	00:00	03/09/88	305	4.23		
458	01:00	Wednesday	319	4.44		
459	02:00		330	4.61		
460	03:00		444	6.34		
461	04:00		394	5.58		
462	05:00		371	5.23		
463	06:00		381	5.38		
464	07:00		352	4.94		
465	08:00		432	6.16		
466	09:00		410	5.82		
467	10:00		412	5.85		
468	11:00		423	6.02		
469	12:00		434	6.19		
470	13:00		355	4.99		
471	14:00		316	4.40		
472	15:00		285	3.93		
473	16:00		346	4.85		
474	17:00		399	5.66		
475	18:00		346	4.85		
476	19:00		363	5.11		
477	20:00		337	4.72		
478	21:00		350	4.91		
479	22:00		401	5.69		
480	23:00		408	5.79		
481	00:00	03/10/88	390	5.52		
482	01:00	Thursday	355	4.99		
483	02:00		340	4.76		
484	03:00		349	4.90	One SPS level	
485	04:00		354	4.97	For 282-489	
486	05:00		350	4.91	Minimum-	2.99 pCi/l
487	06:00		314	4.37	Maximum-	9.23
488	07:00		317	4.41	Average-	5.78
489	08:00		281	3.87	Std.Dev.-	1.29
490	09:00		302	4.19	Fan off 8:30am	
491	10:00		321	4.47	Install 2nd	
492	11:00		368	5.19	Suction pt.	
493	12:00		407	5.78	on at 11:40am	
494	13:00		471	6.75		
495	14:00		441	6.29		
496	15:00		388	5.49		
497	16:00		282	3.88		
498	17:00		278	3.82		
499	18:00		224	3.00		
500	19:00		198	2.61		
501	20:00		230	3.10		
502	21:00		206	2.73		
503	22:00		176	2.28		

DW 29

504	23:00		187	2.44
505	00:00	03/11/88	180	2.34
506	01:00	Friday	189	2.47
507	02:00		174	2.25
508	03:00		211	2.81
509	04:00		203	2.69
510	05:00		212	2.82
511	06:00		193	2.53
512	07:00		242	3.28
513	08:00		231	3.11
514	09:00		228	3.07
515	10:00		222	2.97
516	11:00		239	3.23
517	12:00		219	2.93
518	13:00		202	2.67
519	14:00		197	2.60
520	15:00		190	2.49
521	16:00		228	3.07
522	17:00		217	2.90
523	18:00		198	2.61
524	19:00		188	2.46
525	20:00		172	2.22
526	21:00		167	2.14
527	22:00		129	1.57
528	23:00		117	1.38
529	00:00	03/12/88	160	2.03
530	01:00	Saturday	148	1.85
531	02:00		123	1.47
532	03:00		149	1.87
533	04:00		134	1.64
534	05:00		151	1.90
535	06:00		141	1.75
536	07:00		128	1.55
537	08:00		154	1.94
538	09:00		142	1.76
539	10:00		140	1.73
540	11:00		200	2.64
541	12:00		218	2.91
542	13:00		244	3.31
543	14:00		212	2.82
544	15:00		183	2.38
545	16:00		209	2.78
546	17:00		197	2.60
547	18:00		189	2.47
548	19:00		172	2.22
549	20:00		222	2.97
550	21:00		181	2.35
551	22:00		142	1.76
552	23:00		207	2.75
553	00:00	03/13/88	194	2.55
554	01:00	Sunday	188	2.46

DW 29

555	02:00		188	2.46
556	03:00		186	2.43
557	04:00		211	2.81
558	05:00		181	2.35
559	06:00		175	2.26
560	07:00		203	2.69
561	08:00		167	2.14
562	09:00		189	2.47
563	10:00		165	2.11
564	11:00		173	2.23
565	12:00		217	2.90
566	13:00		213	2.84
567	14:00		166	2.13
568	15:00		202	2.67
569	16:00		183	2.38
570	17:00		173	2.23
571	18:00		166	2.13
572	19:00		165	2.11
573	20:00		185	2.41
574	21:00		176	2.28
575	22:00		174	2.25
576	23:00		167	2.14
577	00:00	03/14/88	149	1.87
578	01:00	Monday	159	2.02
579	02:00		147	1.84
580	03:00		152	1.91
581	04:00		166	2.13
582	05:00		180	2.34
583	06:00		192	2.52
584	07:00		221	2.96
585	08:00		206	2.73
586	09:00		213	2.84
587	10:00		189	2.47
588	11:00		198	2.61
589	12:00		216	2.88
590	13:00		230	3.10
591	14:00		190	2.49
592	15:00		213	2.84
593	16:00		223	2.99
594	17:00		240	3.25
595	18:00		198	2.61
596	19:00		204	2.70
597	20:00		214	2.85
598	21:00		204	2.70
599	22:00		213	2.84
600	23:00		225	3.02
601	00:00	03/15/88	217	2.90
602	01:00	Tuesday	245	3.32
603	02:00		265	3.63
604	03:00		237	3.20
605	04:00		245	3.32

DW 29

606	05:00		233	3.14	
607	06:00		251	3.41	
608	07:00		256	3.49	
609	08:00		261	3.57	
610	09:00		221	2.96	
611	10:00		273	3.75	House closed and
612	11:00		304	4.22	heat off from
613	12:00		296	4.10	10:30am to
614	13:00		380	5.37	3:15pm
615	14:00		354	4.97	
616	15:00		278	3.82	
617	16:00		295	4.08	
618	17:00		248	3.37	
619	18:00		218	2.91	
620	19:00		200	2.64	
621	20:00		189	2.47	
622	21:00		178	2.31	
623	22:00		188	2.46	
624	23:00		206	2.73	
625	00:00	03/16/88	172	2.22	
626	01:00	Wednesday	195	2.57	
627	02:00		210	2.79	
628	03:00		222	2.97	
629	04:00		206	2.73	
630	05:00		203	2.69	
631	06:00		240	3.25	
632	07:00		270	3.70	
633	08:00		264	3.61	
634	09:00		268	3.67	
635	10:00		216	2.88	
636	11:00		272	3.73	
637	12:00		224	3.00	
638	13:00		192	2.52	
639	14:00		180	2.34	
640	15:00		167	2.14	
641	16:00		188	2.46	
642	17:00		204	2.70	
643	18:00		192	2.52	
644	19:00		171	2.20	
645	20:00		190	2.49	
646	21:00		209	2.78	
647	22:00		199	2.63	
648	23:00		206	2.73	
649	00:00	03/17/88	188	2.46	
650	01:00	Thursday	191	2.50	
651	02:00		220	2.94	
652	03:00		215	2.87	
653	04:00		212	2.82	
654	05:00		208	2.76	
655	06:00		243	3.29	
656	07:00		251	3.41	

DW 29

657	08:00	239	3.23			
658	09:00	213	2.84			
659	10:00	183	2.38	2 SPS level		
660	11:00	205	2.72	For 499-664		
661	12:00	166	2.13	Minimum=	1.38	pCi/l
662	13:00	172	2.22	Maximum=	5.37	
663	14:00	155	1.96	Average=	2.67	
664	15:00	137	1.69	Std.Dev.=	0.60	

Dp Measurements for Sub-poly suction systems.

Distance from Suction Point (ft)	Dp (inches of water) DW29 1 pt.	DW29 2 Pts. Pt. A	DW29 2 Pts. Pt. B
0	-1.274	-0.958	-0.97
2	-0.062	-0.078	-0.034
3			
4			
6	-0.01	-0.011	-0.009
12	0	0	-0.001
Q(cfm)	87.3	104.8	104.8

House DW 31	Continuous Radon Monitor				
Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.38	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	11/29/87	0	0.00	
2	01:00	Sunday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		0	0.00	
17	16:00		0	0.00	
18	17:00		1130	16.73	Start Pre-Mitigation
19	18:00		1398	20.79	Monitoring AB5#1
20	19:00		1531	22.81	
21	20:00		1578	23.52	
22	21:00		1501	22.35	
23	22:00		1477	21.99	
24	23:00		1480	22.04	
25	00:00	11/30/87	1505	22.41	
26	01:00	Monday	1442	21.46	
27	02:00		1550	23.10	
28	03:00		1640	24.46	
29	04:00		1628	24.28	
30	05:00		1653	24.66	
31	06:00		1636	24.40	
32	07:00		1626	24.25	
33	08:00		1620	24.16	
34	09:00		1689	25.20	
35	10:00		1730	25.82	
36	11:00		1676	25.00	
37	12:00		1696	25.31	
38	13:00		1570	23.40	
39	14:00		1564	23.31	
40	15:00		1488	22.16	
41	16:00		1510	22.49	
42	17:00		1470	21.88	
43	18:00		1525	22.72	
44	19:00		1583	23.60	

DW 31

45	20:00		1469	21.87			
46	21:00		1520	22.64			
47	22:00		1512	22.52			
48	23:00		1567	23.35			
49	00:00	12/01/87	1558	23.22			
50	01:00	Tuesday	1606	23.94			
51	02:00		1752	26.16			
52	03:00		1786	26.67			
53	04:00		1853	27.69			
54	05:00		2040	30.52			
55	06:00		2061	30.84			
56	07:00		2048	30.64			
57	08:00		2001	29.93			
58	09:00		1946	29.10			
59	10:00		1859	27.78	Pre-mit level		
60	11:00		1819	27.17	For 20-64		
61	12:00		1579	23.54	Minimum-	21.46	pCi/l
62	13:00		1677	25.02	Maximum-	30.84	
63	14:00		1456	21.67	Average-	24.55	
64	15:00		1593	23.75	Std.Dev.-	2.54	
65	16:00				Stop Pre-Mitigation		
66	17:00				Monitoring		
67	18:00						
68	19:00						
69	20:00						
70	21:00						
71	22:00						
72	23:00						
73	00:00	12/02/87					
74	01:00						
75	02:00						
76	03:00						
77	04:00						
78	05:00						
79	06:00						
80	07:00						
81	08:00						
82	09:00						
83	10:00						
84	11:00						
85	12:00						
86	13:00						
87	14:00						
88	15:00						
89	16:00						
90	17:00						
91	18:00						
92	19:00						
93	20:00						
94	21:00						
95	22:00						

DW 31

96	23:00				
97	00:00	12/03/87			
98	01:00				
99	02:00				
100	03:00				
101	04:00				
102	05:00				
103	06:00				
104	07:00				
105	08:00				
106	09:00				
107	10:00				
108	11:00				
109	12:00				
110	13:00				
111	14:00				
112	15:00				
113	16:00				
114	17:00				
115	18:00				
116	19:00				
117	20:00				
118	21:00				
119	22:00				
120	23:00				
121	00:00	12/04/87			
122	01:00	Friday			
123	02:00				
124	03:00				
125	04:00				
126	05:00				
127	06:00				
128	07:00				
129	08:00				
130	09:00				
131	10:00		796	11.52	
132	11:00		1225	18.02	Start Post-Mitigation
133	12:00		1422	21.01	Monitoring 2 Pits on
134	13:00		1221	17.96	at 1:45pm 12/4/87
135	14:00		1132	16.62	AB5#3
136	15:00		871	12.66	
137	16:00		712	10.25	
138	17:00		667	9.57	
139	18:00		669	9.60	
140	19:00		650	9.31	
141	20:00		730	10.52	
142	21:00		722	10.40	
143	22:00		799	11.57	
144	23:00		886	12.89	
145	00:00	12/05/87	992	14.49	
146	01:00	Saturday	940	13.71	

DW 31

147	02:00		1019	14.90	
148	03:00		1005	14.69	
149	04:00		1024	14.98	
150	05:00		1019	14.90	
151	06:00		1001	14.63	
152	07:00		999	14.60	
153	08:00		907	13.21	
154	09:00		865	12.57	
155	10:00		825	11.96	
156	11:00		748	10.80	
157	12:00		721	10.39	
158	13:00		592	8.43	
159	14:00		539	7.63	
160	15:00		480	6.74	
161	16:00		412	5.71	
162	17:00		341	4.63	
163	18:00		304	4.07	
164	19:00		308	4.13	
165	20:00		331	4.48	
166	21:00		401	5.54	
167	22:00		454	6.34	
168	23:00		499	7.02	
169	00:00	12/06/87	522	7.37	
170	01:00	Sunday	604	8.62	
171	02:00		733	10.57	
172	03:00		798	11.55	
173	04:00		871	12.66	
174	05:00		808	11.71	
175	06:00		831	12.05	
176	07:00		888	12.92	
177	08:00		785	11.36	
178	09:00		730	10.52	
179	10:00		632	9.04	
180	11:00		610	8.71	
181	12:00		591	8.42	
182	13:00		583	8.30	
183	14:00		625	8.93	
184	15:00		552	7.83	
185	16:00		515	7.27	
186	17:00		467	6.54	
187	18:00		488	6.86	
188	19:00		538	7.62	
189	20:00		476	6.68	
190	21:00		485	6.81	
191	22:00		476	6.68	
192	23:00		523	7.39	
193	00:00	12/07/87	487	6.84	
194	01:00	Monday	517	7.30	
195	02:00		626	8.95	
196	03:00		618	8.83	2 Pit soil depress level
197	04:00		590	8.40	For 136-201

DW 31

198	05:00		554	7.86	Minimum-	4.07	pCi/l
199	06:00		549	7.78	Maximum-	14.98	
200	07:00		560	7.95	Average-	9.48	
201	08:00		556	7.89	Std.Dev.-	2.93	
202	09:00		547	7.75	All 4 Pits Active		
203	10:00		541	7.66			
204	11:00		524	7.40			
205	12:00		472	6.62			
206	13:00		426	5.92			
207	14:00		399	5.51			
208	15:00		369	5.05			
209	16:00		317	4.27			
210	17:00		302	4.04			
211	18:00		268	3.52			
212	19:00		242	3.13			
213	20:00		226	2.89			
214	21:00		267	3.51			
215	22:00		277	3.66			
216	23:00		282	3.74			
217	00:00	12/08/87	274	3.62			
218	01:00	Tuesday	284	3.77			
219	02:00		278	3.68			
220	03:00		265	3.48			
221	04:00		244	3.16	4 Pit soil depress		
222	05:00		222	2.83	For 204-226		
223	06:00		211	2.66	Minimum-	2.66	pCi/l
224	07:00		249	3.24	Maximum-	7.40	
225	08:00		217	2.75	Average-	3.97	
226	09:00		227	2.90	Std.Dev.-	1.25	
					Stop Post-Mitigation Monitoring		

DW 31

Pressure Field Measured in Soil

Pits Active	Point for Dp	Distance to Source (ft)	Dp Relative to C/S ("H2O)	Fan Flowrate (cfm)
AB	A	0	-1.48	
AB	1	2	-0.03	
AB	2	6	-0.001	
AB	3	12	0	
AB	4	2	-0.071	
AB	5	6	-0.013	
AB	6	12	-0.011	
ABCD	A	0	-0.0921	41.4
ABCD	1	2	-0.145	
ABCD	2	6	-0.007	
ABCD	3	12	-0.109	
ABCD	4	2	-0.063	
ABCD	5	6	-0.005	
ABCD	6	12	-0.005	

House DW 41 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	01/22/88	0	0.00	
2	01:00	Friday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		549	7.56	Start AB-5 PRD in Lower Study
16	15:00		698	9.70	AB5 #4
17	16:00		736	10.25	
18	17:00		800	11.17	
19	18:00		792	11.05	
20	19:00		775	10.81	
21	20:00		752	10.48	
22	21:00		730	10.16	
23	22:00		831	11.61	
24	23:00		1005	14.11	
25	00:00	01/23/88	960	13.46	
26	01:00	Saturday	1080	15.19	
27	02:00		1209	17.04	
28	03:00		1234	17.40	
29	04:00		1073	15.09	
30	05:00		1143	16.09	
31	06:00		1241	17.50	
32	07:00		1232	17.37	
33	08:00		1299	18.34	
34	09:00		1189	16.75	
35	10:00		1118	15.73	
36	11:00		960	13.46	
37	12:00		849	11.87	
38	13:00		727	10.12	
39	14:00		759	10.58	
40	15:00		892	12.49	
41	16:00		891	12.47	
42	17:00		920	12.89	
43	18:00		990	13.90	
44	19:00		920	12.89	

DW 41

45	20:00		1014	14.24
46	21:00		1017	14.28
47	22:00		1060	14.90
48	23:00		1101	15.49
49	00:00	01/24/88	1107	15.58
50	01:00	Sunday	1167	16.44
51	02:00		1083	15.23
52	03:00		1066	14.99
53	04:00		1050	14.76
54	05:00		1190	16.77
55	06:00		1291	18.22
56	07:00		1383	19.54
57	08:00		1345	19.00
58	09:00		1293	18.25
59	10:00		1306	18.44
60	11:00		1202	16.94
61	12:00		1044	14.67
62	13:00		973	13.65
63	14:00		1045	14.69
64	15:00		1095	15.40
65	16:00		1446	20.45
66	17:00		1633	23.13
67	18:00		1584	22.43
68	19:00		1411	19.94
69	20:00		1373	19.40
70	21:00		1305	18.42
71	22:00		1100	15.48
72	23:00		1110	15.62
73	00:00	01/25/88	1178	16.60
74	01:00	Monday	1353	19.11
75	02:00		1385	19.57
76	03:00		1332	18.81
77	04:00		1537	21.75
78	05:00		1447	20.46
79	06:00		1280	18.06
80	07:00		1331	18.79
81	08:00		1307	18.45
82	09:00		1278	18.03
83	10:00		1250	17.63
84	11:00		1228	17.31
85	12:00		1261	17.79
86	13:00		1283	18.11
87	14:00		1191	16.78
88	15:00		1027	14.43
89	16:00		1150	16.19
90	17:00		1180	16.63
91	18:00		1173	16.52
92	19:00		1134	15.96
93	20:00		1123	15.81
94	21:00		976	13.69
95	22:00		905	12.67

DW 41

96	23:00		1064	14.96	
97	00:00	01/26/88	1225	17.27	
98	01:00	Tuesday	1347	19.02	
99	02:00		1459	20.63	
100	03:00		1544	21.86	
101	04:00		1608	22.77	
102	05:00		1452	20.53	
103	06:00		1488	21.05	
104	07:00		1504	21.28	
105	08:00		1513	21.41	
106	09:00		1432	20.25	
107	10:00		1287	18.16	
108	11:00		1321	18.65	
109	12:00		1184	16.68	
110	13:00		1174	16.54	
111	14:00		1255	17.70	
112	15:00		1557	22.04	
113	16:00		1904	27.03	
114	17:00		1829	25.95	
115	18:00		2001	28.42	
116	19:00		2232	31.74	
117	20:00		2169	30.84	
118	21:00		2018	28.67	
119	22:00		1871	26.55	
120	23:00		1673	23.71	
121	00:00	01/27/88	1713	24.28	
122	01:00	Wednesday	1672	23.69	Pre-mit level
123	02:00		1709	24.23	For 12-127
124	03:00		1567	22.19	Minimum- 10.12 pCi/l
125	04:00		1721	24.40	Maximum- 31.74
126	05:00		1713	24.28	Average- 17.86
127	06:00		1583	22.42	Std.Dev.- 4.43
128	07:00		1678	23.78	
129	08:00		1746	24.76	
130	09:00		1657	23.48	
131	10:00		1580	22.37	
132	11:00		1556	22.03	
133	12:00		1377	19.46	
134	13:00		2779	39.60	SubSlab Pressurization
135	14:00		3155	45.00	Fan on at 12:05 pm
136	15:00		2413	34.34	
137	16:00		1939	27.53	
138	17:00		1872	26.57	
139	18:00		1806	25.62	
140	19:00		1618	22.92	
141	20:00		1577	22.33	
142	21:00		1518	21.48	
143	22:00		1414	19.99	
144	23:00		1249	17.62	
145	00:00	01/28/88	1134	15.96	
146	01:00	Thursday	1156	16.28	

DW 41

147	02:00		1126	15.85
148	03:00		1052	14.79
149	04:00		1030	14.47
150	05:00		920	12.89
151	06:00		946	13.26
152	07:00		913	12.79
153	08:00		934	13.09
154	09:00		866	12.11
155	10:00		828	11.57
156	11:00		749	10.43
157	12:00		692	9.61
158	13:00		578	7.98
159	14:00		474	6.48
160	15:00		485	6.64
161	16:00		410	5.56
162	17:00		441	6.01
163	18:00		460	6.28
164	19:00		458	6.25
165	20:00		515	7.07
166	21:00		516	7.09
167	22:00		599	8.28
168	23:00		660	9.15
169	00:00	01/29/88	673	9.34
170	01:00	Friday	699	9.71
171	02:00		666	9.24
172	03:00		607	8.39
173	04:00		626	8.67
174	05:00		572	7.89
175	06:00		636	8.81
176	07:00		701	9.74
177	08:00		608	8.41
178	09:00		600	8.29
179	10:00		548	7.54
180	11:00		571	7.88
181	12:00		450	6.14
182	13:00		420	5.71
183	14:00		334	4.47
184	15:00		324	4.33
185	16:00		310	4.13
186	17:00		338	4.53
187	18:00		341	4.57
188	19:00		360	4.84
189	20:00		394	5.33
190	21:00		416	5.65
191	22:00		447	6.09
192	23:00		438	5.96
193	00:00	01/30/88	507	6.96
194	01:00	Saturday	440	5.99
195	02:00		437	5.95
196	03:00		483	6.61
197	04:00		472	6.45

DW 41

198	05:00		492	6.74
199	06:00		435	5.92
200	07:00		464	6.34
201	08:00		507	6.96
202	09:00		440	5.99
203	10:00		478	6.54
204	11:00		402	5.45
205	12:00		349	4.69
206	13:00		327	4.37
207	14:00		300	3.98
208	15:00		300	3.98
209	16:00		275	3.62
210	17:00		293	3.88
211	18:00		302	4.01
212	19:00		260	3.41
213	20:00		308	4.10
214	21:00		345	4.63
215	22:00		406	5.50
216	23:00		392	5.30
217	00:00	01/31/88	353	4.74
218	01:00	Sunday	360	4.84
219	02:00		381	5.15
220	03:00		400	5.42
221	04:00		382	5.16
222	05:00		384	5.19
223	06:00		414	5.62
224	07:00		372	5.02
225	08:00		355	4.77
226	09:00		340	4.56
227	10:00		307	4.08
228	11:00		306	4.07
229	12:00		292	3.87
230	13:00		234	3.03
231	14:00		230	2.98
232	15:00		250	3.26
233	16:00		244	3.18
234	17:00		272	3.58
235	18:00		284	3.75
236	19:00		268	3.52
237	20:00		280	3.69
238	21:00		289	3.82
239	22:00		321	4.28
240	23:00		343	4.60
241	00:00	02/01/88	348	4.67
242	01:00	Monday	346	4.64
243	02:00		346	4.64
244	03:00		351	4.71
245	04:00		323	4.31
246	05:00		346	4.64
247	06:00		367	4.94
248	07:00		367	4.94

DW 41

249	08:00		352	4.73	
250	09:00		326	4.36	
251	10:00		342	4.59	
252	11:00		329	4.40	
253	12:00		262	3.44	
254	13:00		268	3.52	
255	14:00		256	3.35	
256	15:00		272	3.58	
257	16:00		258	3.38	
258	17:00		279	3.68	
259	18:00		280	3.69	
260	19:00		269	3.54	
261	20:00		296	3.92	
262	21:00		314	4.18	
263	22:00		325	4.34	
264	23:00		371	5.00	
265	00:00	02/02/88	390	5.27	
266	01:00	Tuesday	357	4.80	
267	02:00		316	4.21	
268	03:00		305	4.05	
269	04:00		334	4.47	
270	05:00		304	4.04	Sub-slab Press.level
271	06:00		319	4.25	For 157-275
272	07:00		329	4.40	Minimum= 2.98 pCi/l
273	08:00		437	5.95	Maximum= 9.74
274	09:00		463	6.32	Average= 5.35
275	10:00		462	6.31	Std.Dev.= 1.66
276	11:00		509	6.98	
277	12:00		541	7.44	
278	13:00		562	7.75	Fan to Sub-Slab Depress
279	14:00		389	5.26	at 12:30pm 2/2/88
280	15:00		268	3.52	
281	16:00		185	2.33	
282	17:00		109	1.24	
283	18:00		111	1.27	
284	19:00		94	1.02	
285	20:00		67	0.63	
286	21:00		62	0.56	
287	22:00		56	0.48	
288	23:00		50	0.39	
289	00:00	02/03/88	53	0.43	
290	01:00	Wednesday	45	0.32	
291	02:00		69	0.66	
292	03:00		59	0.52	
293	04:00		49	0.38	
294	05:00		47	0.35	
295	06:00		56	0.48	
296	07:00		59	0.52	
297	08:00		69	0.66	
298	09:00		46	0.33	
299	10:00		84	0.88	

DW 41

300	11:00		53	0.43		
301	12:00		42	0.27		
302	13:00		75	0.75		
303	14:00		65	0.61		
304	15:00		87	0.92		
305	16:00		54	0.45		
306	17:00		64	0.59		
307	18:00		56	0.48		
308	19:00		74	0.73		
309	20:00		67	0.63		
310	21:00		72	0.71		
311	22:00		66	0.62		
312	23:00		79	0.81		
313	00:00	02/04/88	74	0.73		
314	01:00	Thursday	64	0.59		
315	02:00		67	0.63		
316	03:00		70	0.68		
317	04:00		33	0.15		
318	05:00		45	0.32		
319	06:00		40	0.25		
320	07:00		51	0.40		
321	08:00		39	0.23		
322	09:00		45	0.32		
323	10:00		46	0.33		
324	11:00		33	0.15		
325	12:00		34	0.16		
326	13:00		36	0.19		
327	14:00		29	0.09		
328	15:00		22	0.00		
329	16:00		40	0.25		
330	17:00		40	0.25		
331	18:00		43	0.29		
332	19:00		34	0.16		
333	20:00		35	0.17		
334	21:00		38	0.22		
335	22:00		40	0.25		
336	23:00		53	0.43		
337	00:00	02/05/88	48	0.36		
338	01:00	Friday	56	0.48		
339	02:00		59	0.52		
340	03:00		53	0.43		
341	04:00		49	0.38		
342	05:00		52	0.42		
343	06:00		51	0.40		
344	07:00		42	0.27	Sub-slab Depress.level	
345	08:00		45	0.32	For 285-349	
346	09:00		37	0.20	Minimum-	0.00 pCi/l
347	10:00		36	0.19	Maximum-	0.92
348	11:00		49	0.38	Average-	0.43
349	12:00		58	0.50	Std.Dev.-	0.20

House DW 43 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	11/29/87	0	0.00	
2	01:00	Sunday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		2172	29.04	Start Pre-Mitigation Monitoring
16	15:00		3163	42.58	AB5 #2
17	16:00		3560	48.00	
18	17:00		3503	47.22	
19	18:00		3545	47.79	
20	19:00		3471	46.78	
21	20:00		3434	46.28	
22	21:00		3316	44.67	
23	22:00		3297	44.41	
24	23:00		3488	47.02	
25	00:00	11/30/87	3280	44.17	
26	01:00	Monday	3309	44.57	
27	02:00		3308	44.56	
28	03:00		3468	46.74	
29	04:00		3407	45.91	
30	05:00		3309	44.57	
31	06:00		3387	45.64	
32	07:00		3262	43.93	
33	08:00		3254	43.82	
34	09:00		3207	43.18	
35	10:00		3248	43.74	
36	11:00		3462	46.66	
37	12:00		3471	46.78	
38	13:00		3550	47.86	
39	14:00		3661	49.38	
40	15:00		3708	50.02	
41	16:00		3617	48.78	
42	17:00		3457	46.59	
43	18:00		3635	49.02	
44	19:00		3743	50.50	

DW 43

45	20:00		3657	49.33		
46	21:00		3666	49.45		
47	22:00		3500	47.18		
48	23:00		3592	48.44		
49	00:00	12/01/87	3643	49.13		
50	01:00	Tuesday	3629	48.94		
51	02:00		3508	47.29		
52	03:00		3307	44.54		
53	04:00		3391	45.69		
54	05:00		3460	46.63		
55	06:00		3345	45.06		
56	07:00		3211	43.23		
57	08:00		3266	43.98	Pre-mit level	
58	09:00		3134	42.18	For 17-62	
59	10:00		3096	41.66	Minimum-	41.66 pCi/l
60	11:00		3188	42.92	Maximum-	50.50
61	12:00		3281	44.19	Average-	46.16
62	13:00		3339	44.98	Std.Dev.-	2.23
63	14:00				Stop Pre-Mitigation Monitor	
64	15:00					
65	16:00					
66	17:00					
67	18:00					
68	19:00					
69	20:00					
70	21:00					
71	22:00					
72	23:00					
73	00:00	12/02/87				
74	01:00	Wednesday				
75	02:00					
76	03:00					
77	04:00					
78	05:00					
79	06:00					
80	07:00					
81	08:00					
82	09:00					
83	10:00					
84	11:00					
85	12:00					
86	13:00					
87	14:00					
88	15:00					
89	16:00					
90	17:00					
91	18:00					
92	19:00					
93	20:00					
94	21:00					
95	22:00					

DW 43

96	23:00				
97	00:00	12/03/87			
98	01:00	Thursday			
99	02:00				
100	03:00				
101	04:00				
102	05:00				
103	06:00				
104	07:00				
105	08:00				
106	09:00				
107	10:00				
108	11:00				
109	12:00				
110	13:00				
111	14:00				
112	15:00				
113	16:00				
114	17:00				
115	18:00				
116	19:00				
117	20:00				
118	21:00				
119	22:00				
120	23:00				
121	00:00	12/04/87			
122	01:00	Friday			
123	02:00				
124	03:00				
125	04:00				
126	05:00				
127	06:00				
128	07:00				
129	08:00				
130	09:00				
131	10:00				
132	11:00		1099	14.38	Sub-Slab Suction
133	12:00		1943	25.91	Point A On
134	13:00		2417	32.39	AB5 #2
135	14:00		2654	35.62	
136	15:00		2724	36.58	
137	16:00		2663	35.75	*extrapolated
138	17:00		2602	34.91	
139	18:00		2850	38.30	
140	19:00		2883	38.75	
141	20:00		2578	34.58	
142	21:00		2669	35.83	
143	22:00		2816	37.84	
144	23:00		2754	36.99	
145	00:00	12/05/87	2754	36.99	
146	01:00	Saturday	2674	35.90	

DW 43

147	02:00		2636	35.38		
148	03:00		2673	35.88		
149	04:00		2677	35.94		
150	05:00		2610	35.02		
151	06:00		2534	33.98		
152	07:00		2339	31.32		
153	08:00		2196	29.37		
154	09:00		2087	27.88		
155	10:00		2151	28.75		
156	11:00		2209	29.54		
157	12:00		2331	31.21		
158	13:00		2371	31.76		
159	14:00		2526	33.87		
160	15:00		2449	32.82		
161	16:00		2338	31.31		
162	17:00		2380	31.88		
163	18:00		2517	33.75		
164	19:00		2639	35.42		
165	20:00		2553	34.24		
166	21:00		2602	34.91		
167	22:00		2436	32.64		
168	23:00		2506	33.60		
169	00:00	12/06/87	2448	32.81		
170	01:00	Sunday	2496	33.46		
171	02:00		2397	32.11		
172	03:00		2464	33.03		
173	04:00		2458	32.95		
174	05:00		2465	33.04		
175	06:00		2382	31.91		
176	07:00		2221	29.71	Sub-slab A level	
177	08:00		2210	29.56	For 135-181	
178	09:00		2323	31.10	Minimum-	27.88 pCi/l
179	10:00		2156	28.82	Maximum-	38.75
180	11:00		2283	30.55	Average-	33.36
181	12:00		2274	30.43	Std.Dev.-	2.69
182	13:00				System Off to	
183	14:00				Install Sub-Slab	
184	15:00				Suction B and	
185	16:00				Connect Wall	
186	17:00				Suction	
187	18:00					
188	19:00					
189	20:00					
190	21:00					
191	22:00					
192	23:00					
193	00:00	12/07/87				
194	01:00	Monday				
195	02:00					
196	03:00					
197	04:00					

DW 43

198	05:00	
199	06:00	
200	07:00	
201	08:00	
202	09:00	
203	10:00	
204	11:00	
205	12:00	
206	13:00	
207	14:00	
208	15:00	
209	16:00	
210	17:00	
211	18:00	
212	19:00	
213	20:00	
214	21:00	
215	22:00	
216	23:00	
217	00:00	12/08/87
218	01:00	Tuesday
219	02:00	
220	03:00	
221	04:00	
222	05:00	
223	06:00	
224	07:00	
225	08:00	
226	09:00	
227	10:00	
228	11:00	
229	12:00	
230	13:00	
231	14:00	
232	15:00	
233	16:00	
234	17:00	
235	18:00	
236	19:00	
237	20:00	
238	21:00	
239	22:00	
240	23:00	
241	00:00	12/09/87
242	01:00	Wednesday
243	02:00	
244	03:00	
245	04:00	
246	05:00	
247	06:00	
248	07:00	

DW 43

249	08:00					
250	09:00					
251	10:00				Dp Measurements	
252	11:00		374	5.28	Both Sub-Slab and	
253	12:00		738	10.79	Wall Suction Points	
254	13:00		859	12.63	On	
255	14:00		932	13.73	AB5 #1	
256	15:00		961	14.17		
257	16:00		1093	16.17	Doing Dp, Fans off/on/off	
258	17:00		1721	25.69		
259	18:00		2650	39.76		
260	19:00		2497	37.44		
261	20:00		2347	35.17		
262	21:00		2599	38.99		
263	22:00		2319	34.75		
264	23:00		2455	36.81		
265	00:00	12/10/87	1936	28.94		
266	01:00	Thursday	1735	25.90		
267	02:00		1623	24.20		
268	03:00		1656	24.70		
269	04:00		1613	24.05		
270	05:00		1549	23.08		
271	06:00		1596	23.79		
272	07:00		1628	24.28	2 SSS+Wall level	
273	08:00		1382	20.55	For 258-277	
274	09:00		1289	19.14	Minimum=	16.38 pCi/l
275	10:00		1201	17.81	Maximum=	39.76
276	11:00		1195	17.72	Average=	26.96
277	12:00		1107	16.38	Std.Dev.-	7.37
278	13:00				Stop Post-Mitigation	
279	14:00				Monitoring	
280	15:00					
281	16:00					
282	17:00					
283	18:00					
284	19:00					
285	20:00					
286	21:00					
287	22:00					
288	23:00					
289	00:00	01/12/88				
290	01:00	Tuesday				
291	02:00					
292	03:00					
293	04:00					
294	05:00					
295	06:00					
296	07:00					
297	08:00					
298	09:00					
299	10:00					

DW 43

300	11:00				
301	12:00				
302	13:00				
303	14:00				
304	15:00				
305	16:00				
306	17:00				
307	18:00		784	11.49	Counts are on
308	19:00		1037	15.32	:23 after the hour
309	20:00		1291	19.17	AB5 #1
310	21:00		1247	18.50	
311	22:00		1347	20.02	
312	23:00		1225	18.17	
313	00:00	01/13/88	1218	18.07	
314	01:00	Wednesday	1141	16.90	
315	02:00		1029	15.20	
316	03:00		994	14.67	
317	04:00		979	14.44	
318	05:00		951	14.02	
319	06:00		1001	14.78	
320	07:00		1164	17.25	
321	08:00		1121	16.60	
322	09:00		1144	16.94	
323	10:00		1055	15.60	
324	11:00		1033	15.26	
325	12:00		1104	16.34	
326	13:00		1199	17.78	
327	14:00		1186	17.58	
328	15:00		1160	17.19	
329	16:00		1161	17.20	
330	17:00		1094	16.19	
331	18:00		1113	16.47	
332	19:00		1153	17.08	
333	20:00		1175	17.41	
334	21:00		1217	18.05	
335	22:00		1218	18.07	
336	23:00		1082	16.00	
337	00:00	01/14/88	1157	17.14	
338	01:00	Thursday	1083	16.02	
339	02:00		1074	15.88	
340	03:00		1071	15.84	
341	04:00		1014	14.97	
342	05:00		1034	15.28	
343	06:00		1099	16.26	
344	07:00		1058	15.64	
345	08:00		992	14.64	
346	09:00		1161	17.20	
347	10:00		1083	16.02	
348	11:00		1041	15.38	
349	12:00		1100	16.28	
350	13:00		1174	17.40	

DW 43

351	14:00		1085	16.05
352	15:00		1178	17.46
353	16:00		1138	16.85
354	17:00		1216	18.04
355	18:00		1153	17.08
356	19:00		1218	18.07
357	20:00		1164	17.25
358	21:00		1203	17.84
359	22:00		1192	17.67
360	23:00		1139	16.87
361	00:00	01/15/88	1137	16.84
362	01:00	Friday	1061	15.69
363	02:00		1035	15.29
364	03:00		1049	15.50
365	04:00		1085	16.05
366	05:00		1146	16.97
367	06:00		1080	15.97
368	07:00		1068	15.79
369	08:00		1095	16.20
370	09:00		1112	16.46
371	10:00		1050	15.52
372	11:00		1147	16.99
373	12:00		1154	17.10
374	13:00		1298	19.28
375	14:00		1345	19.99
376	15:00		1344	19.97
377	16:00		1269	18.84
378	17:00		1351	20.08
379	18:00		1233	18.29
380	19:00		1312	19.49
381	20:00		1215	18.02
382	21:00		1288	19.13
383	22:00		1256	18.64
384	23:00		1226	18.19
385	00:00	01/16/88	1235	18.32
386	01:00	Saturday	1278	18.97
387	02:00		1150	17.04
388	03:00		1142	16.91
389	04:00		1154	17.10
390	05:00		1103	16.32
391	06:00		1110	16.43
392	07:00		1091	16.14
393	08:00		1089	16.11
394	09:00		1108	16.40
395	10:00		1077	15.93
396	11:00		1187	17.60
397	12:00		1235	18.32
398	13:00		1263	18.75
399	14:00		1342	19.94
400	15:00		1328	19.73
401	16:00		1301	19.32

DW 43

402	17:00		1250	18.55
403	18:00		1199	17.78
404	19:00		1562	23.28
405	20:00		1489	22.17
406	21:00		1344	19.97
407	22:00		1276	18.94
408	23:00		1144	16.94
409	00:00	01/17/88	1258	18.67
410	01:00	Sunday	1231	18.26
411	02:00		1187	17.60
412	03:00		1149	17.02
413	04:00		1146	16.97
414	05:00		1168	17.31
415	06:00		1256	18.64
416	07:00		1170	17.34
417	08:00		1554	23.16
418	09:00		1429	21.26
419	10:00		1335	19.84
420	11:00		1217	18.05
421	12:00		1214	18.00
422	13:00		1172	17.37
423	14:00		1130	16.73
424	15:00		1362	20.25
425	16:00		1207	17.90
426	17:00		1222	18.13
427	18:00		1192	17.67
428	19:00		1261	18.72
429	20:00		1184	17.55
430	21:00		1255	18.63
431	22:00		1204	17.85
432	23:00		1252	18.58
433	00:00	01/18/88	1260	18.70
434	01:00	Monday	1161	17.20
435	02:00		1144	16.94
436	03:00		1218	18.07
437	04:00		1157	17.14
438	05:00		1134	16.79
439	06:00		1249	18.54
440	07:00		1373	20.41
441	08:00		1283	19.05
442	09:00		1271	18.87
443	10:00		1337	19.87
444	11:00		1297	19.26
445	12:00		1122	16.61
446	13:00		1207	17.90
447	14:00		977	14.41
448	15:00		1380	20.52
449	16:00		1552	23.13
450	17:00		1366	20.31
451	18:00		1295	19.23
452	19:00		1305	19.38

DW 43

453	20:00		1262	18.73
454	21:00		1375	20.44
455	22:00		1798	26.85
456	23:00		2033	30.41
457	00:00	01/19/88	2127	31.84
458	01:00	Tuesday	2019	30.20
459	02:00		2375	35.60
460	03:00		2515	37.72
461	04:00		2563	38.44
462	05:00		2755	41.35
463	06:00		3320	49.91
464	07:00		2614	39.22
465	08:00		1737	25.93
466	09:00		1529	22.78
467	10:00		1517	22.60
468	11:00		1692	25.25
469	12:00		1863	27.84
470	13:00		1697	25.32
471	14:00		1547	23.05
472	15:00		1245	18.47
473	16:00		1091	16.14
474	17:00		1335	19.84
475	18:00		1548	23.07
476	19:00		1406	20.91
477	20:00		1246	18.49
478	21:00		1120	16.58
479	22:00		1137	16.84
480	23:00		1362	20.25
481	00:00	01/20/88	1457	21.69
482	01:00	Tuesday	1691	25.23
483	02:00		1858	27.76
484	03:00		2052	30.70
485	04:00		1842	27.52
486	05:00		1566	23.34
487	06:00		1409	20.96
488	07:00		1522	22.67
489	08:00		1527	22.75
490	09:00		1347	20.02
491	10:00		1144	16.94
492	11:00		1174	17.40
493	12:00		1103	16.32
494	13:00		1192	17.67
495	14:00		1068	15.79
496	15:00		387	5.47
497	16:00		167	2.14
498	17:00		72	0.70
499	18:00		45	0.29
500	19:00		35	0.14
501	20:00		56	0.46
502	21:00		329	4.60
503	22:00		889	13.08

DW 43

504	23:00		968	14.28	
505	00:00	01/21/88	861	12.66	
506	01:00	Wednesday	1642	24.49	
507	02:00		1962	29.34	
508	03:00		1296	19.25	
509	04:00		1140	16.88	
510	05:00		1042	15.40	
511	06:00		997	14.72	
512	07:00		1196	17.73	
513	08:00		1561	23.26	
514	09:00		1651	24.63	
515	10:00		1335	19.84	
516	11:00		1113	16.47	
517	12:00		1094	16.19	
518	13:00		1168	17.31	
519	14:00		1160	17.19	
520	15:00		1106	16.37	
521	16:00		1095	16.20	
522	17:00		1159	17.17	
523	18:00		1213	17.99	
524	19:00		1194	17.70	
525	20:00		1135	16.81	
526	21:00		1182	17.52	
527	22:00		1235	18.32	
528	23:00		1313	19.50	
529	00:00	01/22/88	1230	18.25	
530	01:00	Thursday	1135	16.81	
531	02:00		1131	16.75	
532	03:00		1143	16.93	
533	04:00		1143	16.93	
534	05:00		1097	16.23	
535	06:00		1008	14.88	
536	07:00		1178	17.46	2 SSS+wall level
537	08:00		1089	16.11	For 307-541
538	09:00		1107	16.38	Minimum- 0.14 pCi/l
539	10:00		1153	17.08	Maximum- 49.91
540	11:00		1218	18.07	Average- 18.47
541	12:00		1181	17.50	Std.Dev.- 5.55
542	13:00		443	6.32	
543	14:00		168	2.16	
544	15:00				
545	16:00				
546	17:00				
547	18:00				
548	19:00				
549	20:00				
550	21:00				
551	22:00				
552	23:00				
553	00:00	03/17/88			
554	01:00	Thursday			

DW 43

555	02:00				
556	03:00				
557	04:00				
558	05:00				
559	06:00				
560	07:00				
561	08:00				
562	09:00				
563	10:00				
564	11:00				
565	12:00				
566	13:00				
567	14:00				
568	15:00				
569	16:00				
570	17:00				
571	18:00		165	2.04	Levels after
572	19:00		233	3.02	sealing block wall
573	20:00		272	3.58	Counts 15 min before hour
574	21:00		302	4.01	AB5 #4
575	22:00		313	4.17	
576	23:00		259	3.39	
577	00:00	03/18/88	248	3.23	
578	01:00	Friday	290	3.84	
579	02:00		298	3.95	
580	03:00		307	4.08	
581	04:00		358	4.81	
582	05:00		336	4.50	
583	06:00		305	4.05	
584	07:00		319	4.25	
585	08:00		353	4.74	
586	09:00		339	4.54	
587	10:00		317	4.23	
588	11:00		296	3.92	
589	12:00		251	3.28	
590	13:00		271	3.56	
591	14:00		254	3.32	
592	15:00		248	3.23	
593	16:00		276	3.64	
594	17:00		268	3.52	
595	18:00		238	3.09	
596	19:00		214	2.75	
597	20:00		218	2.80	
598	21:00		222	2.86	
599	22:00		291	3.85	
600	23:00		293	3.88	
601	00:00	03/19/88	336	4.50	
602	01:00	Saturday	308	4.10	
603	02:00		308	4.10	
604	03:00		318	4.24	
605	04:00		259	3.39	

DW 43

606	05:00		350	4.70
607	06:00		324	4.33
608	07:00		306	4.07
609	08:00		277	3.65
610	09:00		216	2.77
611	10:00		183	2.30
612	11:00		178	2.23
613	12:00		152	1.86
614	13:00		177	2.21
615	14:00		145	1.75
616	15:00		123	1.44
617	16:00		103	1.15
618	17:00		57	0.49
619	18:00		108	1.22
620	19:00		266	3.49
621	20:00		310	4.13
622	21:00		394	5.33
623	22:00		373	5.03
624	23:00		283	3.74
625	00:00	03/20/88	219	2.82
626	01:00	Sunday	185	2.33
627	02:00		177	2.21
628	03:00		169	2.10
629	04:00		159	1:96
630	05:00		189	2.39
631	06:00		142	1.71
632	07:00		200	2.54
633	08:00		173	2.16
634	09:00		208	2.66
635	10:00		183	2.30
636	11:00		166	2.06
637	12:00		179	2.24
638	13:00		147	1.78
639	14:00		150	1.83
640	15:00		98	1.08
641	16:00		131	1.55
642	17:00		137	1.64
643	18:00		201	2.56
644	19:00		262	3.44
645	20:00		271	3.56
646	21:00		337	4.51
647	22:00		317	4.23
648	23:00		295	3.91
649	00:00	03/21/88	285	3.77
650	01:00	Monday	253	3.31
651	02:00		183	2.30
652	03:00		161	1.98
653	04:00		141	1.70
654	05:00		143	1.73
655	06:00		134	1.60
656	07:00		188	2.37

DW 43

657	08:00		227	2.93
658	09:00		245	3.19
659	10:00		260	3.41
660	11:00		308	4.10
661	12:00		351	4.71
662	13:00		308	4.10
663	14:00		379	5.12
664	15:00		346	4.64
665	16:00		373	5.03
666	17:00		345	4.63
667	18:00		329	4.40
668	19:00		372	5.02
669	20:00		446	6.08
670	21:00		415	5.63
671	22:00		351	4.71
672	23:00		303	4.02
673	00:00	03/22/88	307	4.08
674	01:00	Tuesday	315	4.20
675	02:00		333	4.46
676	03:00		291	3.85
677	04:00		331	4.43
678	05:00		406	5.50
679	06:00		326	4.36
680	07:00		394	5.33
681	08:00		375	5.06
682	09:00		343	4.60
683	10:00		315	4.20
684	11:00		276	3.64
685	12:00		370	4.99
686	13:00		368	4.96
687	14:00		313	4.17
688	15:00		308	4.10
689	16:00		275	3.62
690	17:00		270	3.55
691	18:00		271	3.56
692	19:00		311	4.14
693	20:00		421	5.72
694	21:00		433	5.89
695	22:00		433	5.89
696	23:00		477	6.52
697	00:00	03/23/88	511	7.01
698	01:00	Wednesday	599	8.28
699	02:00		527	7.24
700	03:00		536	7.37
701	04:00		581	8.02
702	05:00		552	7.60
703	06:00		505	6.93
704	07:00		560	7.72
705	08:00		536	7.37
706	09:00		428	5.82
707	10:00		313	4.17

DW 43

708	11:00	290	3.84	2 SSS+Wall+seal level	
709	12:00	250	3.26	For 571-713	
710	13:00	229	2.96	Minimum-	0.49 pCi/l
711	14:00	180	2.26	Maximum-	8.28
712	15:00	162	2.00	Average-	3.79
713	16:00	205	2.62	Std.Dev.-	1.53

House DW 60 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	12/01/87	0	0.00	
2	01:00	Tuesday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		0	0.00	
17	16:00		0	0.00	
18	17:00		0	0.00	
19	18:00		1789	26.72	Start Pre-Mitigation Monitoring
20	19:00		1923	28.75	AB5 #1
21	20:00		1869	27.93	
22	21:00		1866	27.88	
23	22:00		1902	28.43	
24	23:00		2021	30.23	
25	00:00	12/02/87	2041	30.54	
26	01:00	Wednesday	1996	29.85	
27	02:00		2055	30.75	
28	03:00		2046	30.61	
29	04:00		2160	32.34	
30	05:00		2157	32.29	
31	06:00		2034	30.43	
32	07:00		2099	31.41	
33	08:00		2112	31.61	
34	09:00		2039	30.50	
35	10:00		2054	30.73	
36	11:00		2040	30.52	
37	12:00		2067	30.93	
38	13:00		1928	28.82	
39	14:00		1895	28.32	
40	15:00		1788	26.70	
41	16:00		1677	25.02	
42	17:00		1679	25.05	
43	18:00		1753	26.17	
44	19:00		1753	26.17	

DW 60

45	20:00		1838	27.46		
46	21:00		1893	28.29		
47	22:00		1986	29.70		
48	23:00		2040	30.52		
49	00:00	12/03/87	1967	29.41		
50	01:00	Thursday	1986	29.70		
51	02:00		1995	29.84		
52	03:00		2112	31.61		
53	04:00		2031	30.38		
54	05:00		1936	28.94		
55	06:00		2082	31.16		
56	07:00		2067	30.93		
57	08:00		1957	29.26		
58	09:00		1985	29.69		
59	10:00		1869	27.93		
60	11:00		1696	25.31	Pre-mit level	
61	12:00		1676	25.00	For 19-65	
62	13:00		1753	26.17	Minimum-	21.67 pCi/l
63	14:00		1681	25.08	Maximum-	32.34
64	15:00		1582	23.58	Average-	28.73
65	16:00		1456	21.67	Std.Dev.-	2.43
66	17:00				Stop Pre-Mitigation Monitor	
67	18:00					
68	19:00					
69	20:00					
70	21:00					
71	22:00					
72	23:00					
73	00:00	12/04/87				
74	01:00	Friday				
75	02:00					
76	03:00					
77	04:00					
78	05:00					
79	06:00					
80	07:00					
81	08:00					
82	09:00					
83	10:00					
84	11:00					
85	12:00					
86	13:00					
87	14:00					
88	15:00					
89	16:00					
90	17:00					
91	18:00					
92	19:00					
93	20:00					
94	21:00					
95	22:00					

DW 60

96	23:00				
97	00:00	12/05/87			
98	01:00	Saturday			
99	02:00				
100	03:00				
101	04:00				
102	05:00				
103	06:00				
104	07:00				
105	08:00				
106	09:00				
107	10:00				
108	11:00				
109	12:00				
110	13:00				
111	14:00				
112	15:00				
113	16:00				
114	17:00				
115	18:00				
116	19:00				
117	20:00				
118	21:00				
119	22:00				
120	23:00				
121	00:00	12/06/87			
122	01:00	Sunday			
123	02:00				
124	03:00				
125	04:00				
126	05:00				
127	06:00				
128	07:00				
129	08:00				
130	09:00				
131	10:00				
132	11:00				
133	12:00				
134	13:00		738	10.79	Start Post-Mitigation Monitor
135	14:00		1187	17.60	Seal/Passive Vent C/S
136	15:00		1342	19.94	AB5 #1
137	16:00		1375	20.44	
138	17:00		1403	20.87	
139	18:00		1458	21.70	
140	19:00		1491	22.20	
141	20:00		1630	24.31	
142	21:00		1717	25.63	
143	22:00		1774	26.49	
144	23:00		1892	28.28	
145	00:00	12/07/87	2007	30.02	
146	01:00	Monday	2126	31.82	

DW 60

147	02:00		2040	30.52	
148	03:00		2077	31.08	
149	04:00		1869	27.93	
150	05:00		1963	29.35	
151	06:00		1920	28.70	
152	07:00		2033	30.41	
153	08:00		1885	28.17	
154	09:00		1774	26.49	
155	10:00		1425	21.20	
156	11:00		1238	18.37	
157	12:00		1178	17.46	
158	13:00		1207	17.90	
159	14:00		1038	15.34	
160	15:00		965	14.23	
161	16:00		603	8.75	
162	17:00		449	6.41	
163	18:00		669	9.75	
164	19:00		770	11.28	
165	20:00		976	14.40	
166	21:00		1142	16.91	
167	22:00		1209	17.93	
168	23:00		1348	20.03	
169	00:00	12/08/87	1318	19.58	
170	01:00	Tuesday	1389	20.66	
171	02:00		1384	20.58	
172	03:00		1292	19.19	
173	04:00		1322	19.64	
174	05:00		1318	19.58	
175	06:00		1385	20.60	Seal+vent c/s level
176	07:00		1368	20.34	For 136-180
177	08:00		1356	20.16	Minimum- 6.41 pCi/l
178	09:00		1224	18.16	Maximum- 31.82
179	10:00		1090	16.13	Average- 20.98
180	11:00		1032	15.25	Std.Dev.- 6.14
181	12:00		997	14.72	
182	13:00		805	11.81	Sub-Poly Suction Fan On, Max.
183	14:00		647	9.41	
184	15:00		469	6.72	
185	16:00		377	5.32	
186	17:00		386	5.46	
187	18:00		311	4.32	
188	19:00		287	3.96	
189	20:00		334	4.67	
190	21:00		352	4.94	
191	22:00		377	5.32	
192	23:00		402	5.70	
193	00:00	12/09/87	384	5.43	
194	01:00	Wednesday	385	5.44	
195	02:00		452	6.46	
196	03:00		534	7.70	
197	04:00		562	8.13	1 SPS level

DW 60

198	05:00		642	9.34	For 183-202	
199	06:00		602	8.73	Minimum-	3.96 pCi/l
200	07:00		607	8.81	Maximum-	9.41
201	08:00		571	8.26	Average-	6.59
202	09:00		533	7.69	Std.Dev.-	1.72
203	10:00				Stop Post-Mitigation Monitor	
204	11:00					
205	12:00					
206	13:00					
207	14:00					
208	15:00					
209	16:00					
210	17:00					
211	18:00					
212	19:00					
213	20:00					
214	21:00					
215	22:00					
216	23:00					
217	00:00	03/24/88				
218	01:00	Thursday				
219	02:00					
220	03:00					
221	04:00					
222	05:00					
223	06:00					
224	07:00					
225	08:00					
226	09:00					
227	10:00					
228	11:00					
229	12:00		28	0.07	AB5 #4	
230	13:00		25	0.03		
231	14:00		27	0.06		
232	15:00		23	0.00		
233	16:00		17	0.00		
234	17:00		20	0.00		
235	18:00		13	0.00		
236	19:00		16	0.00		
237	20:00		18	0.00		
238	21:00		17	0.00		
239	22:00		17	0.00		
240	23:00		17	0.00		
241	00:00	03/25/88	29	0.09		
242	01:00	Friday	56	0.48		
243	02:00		64	0.59		
244	03:00		85	0.89		
245	04:00		68	0.65		
246	05:00		117	1.35		
247	06:00		97	1.06		
248	07:00		81	0.84		

DW 60

249	08:00		126	1.48
250	09:00		131	1.55
251	10:00		127	1.50
252	11:00		129	1.52
253	12:00		64	0.59
254	13:00		62	0.56
255	14:00		62	0.56
256	15:00		72	0.71
257	16:00		46	0.33
258	17:00		32	0.13
259	18:00		28	0.07
260	19:00		22	0.00
261	20:00		29	0.09
262	21:00		44	0.30
263	22:00		54	0.45
264	23:00		130	1.54
265	00:00	03/26/88	173	2.16
266	01:00	Saturday	228	2.95
267	02:00		370	4.99
268	03:00		449	6.12
269	04:00		553	7.62
270	05:00		594	8.21
271	06:00		635	8.79
272	07:00		655	9.08
273	08:00		670	9.30
274	09:00		561	7.73
275	10:00		280	3.69
276	11:00		255	3.34
277	12:00		212	2.72
278	13:00		133	1.58
279	14:00		82	0.85
280	15:00		40	0.25
281	16:00		40	0.25
282	17:00		27	0.06
283	18:00		19	0.00
284	19:00		24	0.02
285	20:00		63	0.58
286	21:00		106	1.19
287	22:00		154	1.88
288	23:00		269	3.54
289	00:00	03/27/88	560	7.72
290	01:00	Sunday	921	12.90
291	02:00		1423	20.12
292	03:00		1564	22.14
293	04:00		1774	25.16
294	05:00		1913	27.16
295	06:00		2075	29.48
296	07:00		2107	29.94
297	08:00		2304	32.77
298	09:00		2223	31.61
299	10:00		2050	29.13

DW 60

300	11:00		1682	23.84	
301	12:00		1435	20.29	
302	13:00		919	12.88	
303	14:00		532	7.31	
304	15:00		320	4.27	
305	16:00		244	3.18	
306	17:00		181	2.27	
307	18:00		156	1.91	
308	19:00		171	2.13	
309	20:00		193	2.44	
310	21:00		240	3.12	
311	22:00		322	4.30	
312	23:00		450	6.14	
313	00:00	03/28/88	574	7.92	
314	01:00	Monday	726	10.10	
315	02:00		668	9.27	
316	03:00		689	9.57	
317	04:00		726	10.10	
318	05:00		679	9.43	
319	06:00		670	9.30	
320	07:00		753	10.49	
321	08:00		811	11.32	
322	09:00		1216	17.14	
323	10:00		859	12.01	
324	11:00		457	6.24	
325	12:00		215	2.76	Kyle-Lefkov
326	13:00		126	1.48	on 12:10pm
327	14:00		113	1.29	
328	15:00		80	0.82	
329	16:00		52	0.42	
330	17:00		35	0.17	
331	18:00		27	0.06	
332	19:00		29	0.09	
333	20:00		38	0.22	
334	21:00		37	0.20	
335	22:00		53	0.43	
336	23:00		51	0.40	
337	00:00	03/29/88	54	0.45	
338	01:00	Tuesday	73	0.72	
339	02:00		125	1.47	
340	03:00		167	2.07	
341	04:00		201	2.56	
342	05:00		174	2.17	
343	06:00		144	1.74	
344	07:00		137	1.64	
345	08:00		127	1.50	
346	09:00		84	0.88	

DW 60

Dp Measurements for Sub-poly suction systems.

Distance from Suction Point (ft)	Dp (inches of water) DW60
0	-1.024
2	
3	-0.379
4	
6	-0.066
12	-0.005
Q(cfm)	

House DW 66	Continuous	Radon Monitor	Results		
Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
-----	-----	-----	-----	-----	-----
1	00:00	12/01/87	0	0.00	
2	01:00	Tuesday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		0	0.00	
17	16:00		0	0.00	
18	17:00		0	0.00	
19	18:00		0	0.00	
20	19:00		595	7.49	Start Pre-Mit
21	20:00		747	9.57	Monitor AB5 #2
22	21:00		810	10.43	
23	22:00		819	10.55	
24	23:00		755	9.68	
25	00:00	12/02/87	793	10.20	
26	01:00	Wednesday	863	11.16	
27	02:00		873	11.29	
28	03:00		896	11.61	
29	04:00		841	10.86	
30	05:00		872	11.28	
31	06:00		835	10.77	
32	07:00		883	11.43	
33	08:00		933	12.11	
34	09:00		928	12.04	
35	10:00		914	11.85	
36	11:00		924	11.99	
37	12:00		861	11.13	
38	13:00		917	11.89	
39	14:00		911	11.81	
40	15:00		957	12.44	
41	16:00		969	12.60	
42	17:00		950	12.34	
43	18:00		1020	13.30	
44	19:00		966	12.56	

DW 66

45	20:00		1076	14.07	
46	21:00		1106	14.48	
47	22:00		1010	13.16	
48	23:00		1040	13.57	
49	00:00	12/03/87	1084	14.17	
50	01:00	Thursday	1022	13.33	
51	02:00		1081	14.13	
52	03:00		1116	14.61	
53	04:00		987	12.85	
54	05:00		919	11.92	
55	06:00		905	11.73	
56	07:00		936	12.15	
57	08:00		911	11.81	
58	09:00		831	10.72	
59	10:00		849	10.96	
60	11:00		722	9.23	
61	12:00		736	9.42	Pre-mit level
62	13:00		772	9.91	For 22-66
63	14:00		732	9.37	Minimum= 8.49 pCi/l
64	15:00		668	8.49	Maximum= 14.61
65	16:00		747	9.57	Average= 11.67
66	17:00		786	10.10	Std.Dev.= 1.49
67	18:00				Stop Pre-Mitigation Monitor
68	19:00				
69	20:00				
70	21:00				
71	22:00				
72	23:00				
73	00:00	12/04/87			
74	01:00	Friday			
75	02:00				
76	03:00				
77	04:00				
78	05:00				
79	06:00				
80	07:00				
81	08:00				
82	09:00				
83	10:00				
84	11:00				
85	12:00				
86	13:00				
87	14:00				
88	15:00				
89	16:00				
90	17:00				
91	18:00				
92	19:00				
93	20:00				
94	21:00				
95	22:00				

DW 66

96	23:00				
97	00:00	12/05/87			
98	01:00	Saturday			
99	02:00				
100	03:00				
101	04:00				
102	05:00				
103	06:00				
104	07:00				
105	08:00				
106	09:00				
107	10:00				
108	11:00				
109	12:00				
110	13:00				
111	14:00				
112	15:00				
113	16:00				
114	17:00				
115	18:00				
116	19:00				
117	20:00				
118	21:00				
119	22:00				
120	23:00				
121	00:00	12/06/87			
122	01:00	Sunday			
123	02:00				
124	03:00				
125	04:00				
126	05:00				
127	06:00				
128	07:00				
129	08:00				
130	09:00				
131	10:00				
132	11:00				
133	12:00				
134	13:00				
135	14:00				Start Post-Mitigation Monitor
136	15:00		1314	17.32	Seal C/S Only
137	16:00		1271	16.73	AB5 #2
138	17:00		1244	16.36	
139	18:00		1245	16.37	
140	19:00		1269	16.70	
141	20:00		1362	17.97	
142	21:00		1259	16.57	
143	22:00		1230	16.17	
144	23:00		1202	15.79	
145	00:00	12/07/87	1236	16.25	
146	01:00	Monday	1207	15.86	

DW 66

147	02:00		1168	15.32		
148	03:00		1193	15.66		
149	04:00		1233	16.21		
150	05:00		1162	15.24		
151	06:00		1207	15.86		
152	07:00		1140	14.94		
153	08:00		1141	14.95		
154	09:00		1131	14.82		
155	10:00		1055	13.78		
156	11:00		1082	14.15		
157	12:00		1023	13.34		
158	13:00		1024	13.36		
159	14:00		952	12.37		
160	15:00		901	11.67		
161	16:00		874	11.31		
162	17:00		848	10.95		
163	18:00		798	10.27		
164	19:00		837	10.80		
165	20:00		874	11.31		
166	21:00		941	12.22		
167	22:00		928	12.04		
168	23:00		855	11.05		
169	00:00	12/08/87	857	11.07		
170	01:00	Tuesday	804	10.35		
171	02:00		801	10.31		
172	03:00		911	11.81		
173	04:00		894	11.58		
174	05:00		888	11.50		
175	06:00		860	11.11		
176	07:00		924	11.99	Seal c/s level	
177	08:00		941	12.22	For 136-181	
178	09:00		849	10.96	Minimum-	10.25 pCi/l
179	10:00		834	10.76	Maximum-	17.97
180	11:00		855	11.05	Average-	13.45
181	12:00		797	10.25	Std.Dev.-	2.39
182	13:00		742	9.50		
183	14:00		743	9.52	Sub-Poly Suction Fan on	
184	15:00		737	9.43	Max Flow at 14:12	
185	16:00		652	8.27		
186	17:00		552	6.91		
187	18:00		543	6.78		
188	19:00		507	6.29		
189	20:00		439	5.36		
190	21:00		440	5.38		
191	22:00		409	4.95		
192	23:00		388	4.67		
193	00:00	12/09/87	364	4.34		
194	01:00	Wednesday	334	3.93		
195	02:00		308	3.57		
196	03:00		292	3.36		
197	04:00		236	2.59		

DW 66

198	05:00		243	2.69		
199	06:00		214	2.29		
200	07:00		270	3.05		
201	08:00		219	2.36		
202	09:00		190	1.96		
203	10:00		189	1.95		
204	11:00		207	2.19		
205	12:00		162	1.58		
206	13:00		153	1.46		
207	14:00		139	1.26		
208	15:00		112	0.90		
209	16:00		87	0.55		
210	17:00		111	0.88		
211	18:00		113	0.91		
212	19:00		120	1.01		
213	20:00		153	1.46		
214	21:00		142	1.31		
215	22:00		149	1.40		
216	23:00		168	1.66		
217	00:00	12/10/87	201	2.11		
218	01:00	Thursday	207	2.19		
219	02:00		269	3.04		
220	03:00		304	3.52		
221	04:00		309	3.59		
222	05:00		407	4.93	1 SPS level	
223	06:00		386	4.64	For 185-227	
224	07:00		446	5.46	Minimum-	0.55 pCi/1
225	08:00		410	4.97	Maximum-	8.27
226	09:00		418	5.08	Average-	3.28
227	10:00		364	4.34	Std.Dev.-	1.90
					Stop Post-Mit Monitor	

Dp Measurements for Sub-poly suction systems.

Distance from Suction Point (ft)	Dp (inches of water) DW66
0	-0.86
2	
3	
4	-0.071
6	-0.013
12	-0.005

Q(cfm)

House DW 78 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
-----	-----	-----	-----	-----	-----
1	00:00	03/04/88	0	0.00	
2	01:00	Friday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		2211	31.44	Start Pre-Mit
14	13:00		2482	35.33	Monitoring AB5 #4
15	14:00		2620	37.31	Fans turned off
16	15:00		2703	38.51	
17	16:00		2644	37.66	
18	17:00		2610	37.17	
19	18:00		2614	37.23	
20	19:00		2665	37.96	
21	20:00		2672	38.06	
22	21:00		2674	38.09	
23	22:00		2627	37.42	
24	23:00		2611	37.19	
25	00:00	03/05/88	2350	33.44	
26	01:00	Saturday	2379	33.85	
27	02:00		2207	31.38	
28	03:00		2168	30.82	
29	04:00		2279	32.42	
30	05:00		2237	31.81	
31	06:00		2202	31.31	
32	07:00		2255	32.07	
33	08:00		2254	32.06	
34	09:00		2344	33.35	
35	10:00		2258	32.11	
36	11:00		2198	31.25	
37	12:00		2213	31.47	
38	13:00		2113	30.03	
39	14:00		2311	32.88	
40	15:00		2255	32.07	
41	16:00		2235	31.78	
42	17:00		2251	32.01	
43	18:00		2337	33.25	
44	19:00		2310	32.86	

DW 78

45	20:00		2357	33.54	
46	21:00		2315	32.93	
47	22:00		2381	33.88	
48	23:00		2434	34.64	
49	00:00	03/06/88	2372	33.75	
50	01:00	Sunday	2321	33.02	
51	02:00		2304	32.77	
52	03:00		2358	33.55	
53	04:00		2385	33.94	
54	05:00		2256	32.09	
55	06:00		2243	31.90	
56	07:00		2310	32.86	
57	08:00		2386	33.95	
58	09:00		2286	32.52	
59	10:00		2306	32.80	
60	11:00		2216	31.51	
61	12:00		2111	30.00	
62	13:00		2212	31.45	
63	14:00		2287	32.53	
64	15:00		2248	31.97	
65	16:00		2048	29.10	
66	17:00		2264	32.20	
67	18:00		2427	34.54	
68	19:00		2526	35.96	
69	20:00		2644	37.66	
70	21:00		2568	36.57	
71	22:00		2636	37.54	
72	23:00		2764	39.38	
73	00:00	03/07/88	2575	36.67	
74	01:00	Monday	2593	36.93	
75	02:00		2516	35.82	
76	03:00		2514	35.79	
77	04:00		2495	35.52	
78	05:00		2467	35.12	
79	06:00		2435	34.66	
80	07:00		2474	35.22	Pre-mit level
81	08:00		2554	36.37	For 15-85
82	09:00		2413	34.34	Minimum= 29.10 pCi/l
83	10:00		2319	32.99	Maximum= 39.38
84	11:00		2291	32.59	Average= 33.96
85	12:00		2244	31.91	Std.Dev.= 2.41
86	13:00		1893	26.87	Sub-Slab
87	14:00		1355	19.14	Fans on 12:15pm
88	15:00		824	11.51	
89	16:00		514	7.06	
90	17:00		391	5.29	
91	18:00		380	5.13	
92	19:00		476	6.51	
93	20:00		605	8.36	
94	21:00		999	14.02	
95	22:00		1265	17.85	

DW 78

96	23:00		1252	17.66
97	00:00	03/08/88	1204	16.97
98	01:00	Tuesday	1040	14.61
99	02:00		939	13.16
100	03:00		902	12.63
101	04:00		846	11.83
102	05:00		904	12.66
103	06:00		775	10.81
104	07:00		835	11.67
105	08:00		729	10.15
106	09:00		751	10.46
107	10:00		676	9.38
108	11:00		522	7.17
109	12:00		397	5.38
110	13:00		347	4.66
111	14:00		245	3.19
112	15:00		209	2.67
113	16:00		198	2.52
114	17:00		184	2.31
115	18:00		230	2.98
116	19:00		253	3.31
117	20:00		257	3.36
118	21:00		296	3.92
119	22:00		312	4.15
120	23:00		347	4.66
121	00:00	03/09/88	420	5.71
122	01:00	Wednesday	437	5.95
123	02:00		483	6.61
124	03:00		483	6.61
125	04:00		425	5.78
126	05:00		353	4.74
127	06:00		396	5.36
128	07:00		416	5.65
129	08:00		447	6.09
130	09:00		458	6.25
131	10:00		410	5.56
132	11:00		351	4.71
133	12:00		357	4.80
134	13:00		461	6.29
135	14:00		474	6.48
136	15:00		545	7.50
137	16:00		481	6.58
138	17:00		594	8.21
139	18:00		567	7.82
140	19:00		587	8.11
141	20:00		585	8.08
142	21:00		621	8.59
143	22:00		549	7.56
144	23:00		515	7.07
145	00:00	03/10/88	407	5.52
146	01:00	Thursday	434	5.91

DW 78

```
147   02:00                  465     6.35
148   03:00                  465     6.35
149   04:00                  423     5.75
150   05:00                  443     6.04
151   06:00                  449     6.12
152   07:00                  445     6.06
153   08:00                  440     5.99
154   09:00                  446     6.08
155   10:00                  431     5.86
156   11:00                  438     5.96
157   12:00                  420     5.71
158   13:00                  430     5.85
159   14:00                  455     6.21
160   15:00                  496     6.80
161   16:00                  499     6.84
162   17:00                  538     7.40
163   18:00                  655     9.08
164   19:00                  607     8.39
165   20:00                  721    10.03
166   21:00                  657     9.11
167   22:00                  695     9.66
168   23:00                  608     8.41
169   00:00 03/11/88         591     8.16
170   01:00 Friday           582     8.03
171   02:00                  594     8.21
172   03:00                  608     8.41 2 SSS level
173   04:00                  580     8.00 For 90-177
174   05:00                  595     8.22 Minimum=      2.31 pCi/l
175   06:00                  614     8.49 Maximum=     17.85
176   07:00                  572     7.89 Average=      7.42
177   08:00                  488     6.68 Std.Dev.=     3.13
178   09:00                  511     7.01
179   10:00                  380     5.13
180   11:00                  279     3.68
181   12:00                  237     3.08
182   13:00                  153     1.87
183   14:00                  112     1.28
184   15:00                   86     0.91
185   16:00                  120     1.40
186   17:00                  131     1.55
187   18:00                  172     2.14
188   19:00                  273     3.59
189   20:00                  389     5.26
190   21:00                  552     7.60
191   22:00                  538     7.40
192   23:00                  501     6.87
193   00:00 03/12/88         410     5.56
194   01:00 Saturday         369     4.97
195   02:00                  382     5.16
196   03:00                  309     4.11
197   04:00                  341     4.57
```

DW 78

198	05:00		290	3.84		
199	06:00		234	3.03		
200	07:00		243	3.16		
201	08:00		217	2.79		
202	09:00		236	3.06		
203	10:00		238	3.09		
204	11:00		224	2.89		
205	12:00		217	2.79		
206	13:00		271	3.56		
207	14:00		298	3.95		
208	15:00		295	3.91		
209	16:00		286	3.78		
210	17:00		278	3.67		
211	18:00		261	3.42		
212	19:00		263	3.45		
213	20:00		247	3.22		
214	21:00		296	3.92		
215	22:00		323	4.31		
216	23:00		332	4.44		
217	00:00	03/13/88	390	5.27		
218	01:00	Sunday	397	5.38		
219	02:00		402	5.45		
220	03:00		379	5.12		
221	04:00		431	5.86		
222	05:00		450	6.14		
223	06:00		400	5.42		
224	07:00		485	6.64		
225	08:00		490	6.71		
226	09:00		434	5.91		
227	10:00		394	5.33		
228	11:00		375	5.06		
229	12:00		381	5.15		
230	13:00		432	5.88		
231	14:00		429	5.84		
232	15:00		414	5.62		
233	16:00		392	5.30		
234	17:00		324	4.33		
235	18:00		336	4.50		
236	19:00		416	5.65		
237	20:00		533	7.33		
238	21:00		588	8.12		
239	22:00		610	8.44		
240	23:00		596	8.23		
241	00:00	03/14/88	553	7.62		
242	01:00	Monday	587	8.11		
243	02:00		522	7.17	2 SSS level	
244	03:00		503	6.90	For 90-250	
245	04:00		458	6.25	Minimum-	0.91 pCi/l
246	05:00		451	6.15	Maximum-	17.85
247	06:00		429	5.84	Average-	6.27
248	07:00		414	5.62	Std.Dev.-	2.89

DW 78

249	08:00		382	5.16	
250	09:00		385	5.20	fans off 10:08am
251	10:00		386	5.22	ins wall suction
252	11:00		411	5.58	cover c/s w/poly
253	12:00		430	5.85	
254	13:00		487	6.67	
255	14:00		571	7.88	
256	15:00		659	9.14	
257	16:00		699	9.71	fans back on
258	17:00		551	7.59	4:05pm
259	18:00		346	4.64	
260	19:00		296	3.92	
261	20:00		269	3.54	
262	21:00		233	3.02	
263	22:00		207	2.65	
264	23:00		224	2.89	
265	00:00	03/15/88	219	2.82	
266	01:00	Tuesday	232	3.00	
267	02:00		233	3.02	
268	03:00		273	3.59	
269	04:00		287	3.79	
270	05:00		280	3.69	
271	06:00		275	3.62	
272	07:00		241	3.13	
273	08:00		248	3.23	
274	09:00		229	2.96	
275	10:00		198	2.52	
276	11:00		246	3.21	
277	12:00		179	2.24	finish seal poly
278	13:00		176	2.20	at 12:20pm
279	14:00		154	1.88	
280	15:00		150	1.83	
281	16:00		123	1.44	
282	17:00		124	1.45	
283	18:00		142	1.71	
284	19:00		161	1.98	
285	20:00		159	1.96	
286	21:00		179	2.24	
287	22:00		178	2.23	
288	23:00		209	2.67	
289	00:00	03/16/88	196	2.49	
290	01:00	Wednesday	184	2.31	
291	02:00		190	2.40	
292	03:00		235	3.05	
293	04:00		238	3.09	
294	05:00		218	2.80	
295	06:00		228	2.95	
296	07:00		247	3.22	
297	08:00		231	2.99	
298	09:00		197	2.50	
299	10:00		198	2.52	

DW 78

300	11:00		168	2.09		
301	12:00		166	2.06		
302	13:00		173	2.16		
303	14:00		167	2.07		
304	15:00		156	1.91		
305	16:00		141	1.70		
306	17:00		155	1.90		
307	18:00		157	1.93		
308	19:00		147	1.78		
309	20:00		182	2.29		
310	21:00		153	1.87		
311	22:00		167	2.07		
312	23:00		156	1.91		
313	00:00	03/17/88	172	2.14		
314	01:00	Thursday	197	2.50		
315	02:00		198	2.52		
316	03:00		192	2.43		
317	04:00		237	3.08		
318	05:00		260	3.41		
319	06:00		277	3.65		
320	07:00		266	3.49		
321	08:00		259	3.39		
322	09:00		226	2.92		
323	10:00		197	2.50		
324	11:00		157	1.93		
325	12:00		147	1.78	2 SSS+Wall+cover/seal c/s	
326	13:00		134	1.60	level For 279-330	
327	14:00		129	1.52	Minimum-	1.12 pCi/l
328	15:00		101	1.12	Maximum-	3.65
329	16:00		113	1.29	Average-	2.27
330	17:00		123	1.44	Std.Dev.-	0.60
					Stop Post-Mit Monitoring	

House DW 82 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	11/29/87	0	0.00	
2	01:00	Sunday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		551	7.81	Start Pre-Mitigation Monitoring
17	16:00		872	12.68	AB5 #3
18	17:00		980	14.31	
19	18:00		1071	15.69	
20	19:00		1061	15.54	
21	20:00		1126	16.52	
22	21:00		1128	16.55	
23	22:00		1154	16.95	
24	23:00		1055	15.45	
25	00:00	11/30/87	1013	14.81	
26	01:00	Monday	1029	15.05	
27	02:00		1154	16.95	
28	03:00		1099	16.12	
29	04:00		1194	17.55	
30	05:00		1241	18.27	
31	06:00		1177	17.30	
32	07:00		1274	18.77	
33	08:00		1325	19.54	
34	09:00		1202	17.68	
35	10:00		1160	17.04	
36	11:00		1080	15.83	
37	12:00		966	14.10	
38	13:00		908	13.22	
39	14:00		918	13.37	
40	15:00		902	13.13	
41	16:00		949	13.84	
42	17:00		939	13.69	
43	18:00		945	13.78	
44	19:00		992	14.49	

DW 82

45	20:00		945	13.78	
46	21:00		985	14.39	
47	22:00		952	13.89	
48	23:00		878	12.77	
49	00:00	12/01/87	889	12.93	
50	01:00	Tuesday	898	13.07	
51	02:00		976	14.25	
52	03:00		987	14.42	
53	04:00		940	13.71	
54	05:00		900	13.10	
55	06:00		981	14.33	
56	07:00		1010	14.77	
57	08:00		954	13.92	Pre-mit level
58	09:00		852	12.37	For 18-62
59	10:00		905	13.18	Minimum- 12.37 pCi/1
60	11:00		954	13.92	Maximum- 19.54
61	12:00		963	14.05	Average- 14.94
62	13:00		947	13.81	Std.Dev.- 1.74
63	14:00				Stop Pre-Mitigation Monitoring
64	15:00				
65	16:00				
66	17:00				
67	18:00				
68	19:00				
69	20:00				
70	21:00				
71	22:00				
72	23:00				
73	00:00	12/02/87			
74	01:00	Wednesday			
75	02:00				
76	03:00				
77	04:00				
78	05:00				
79	06:00				
80	07:00				
81	08:00				
82	09:00				
83	10:00				
84	11:00				
85	12:00				
86	13:00				
87	14:00				
88	15:00				
89	16:00				
90	17:00				
91	18:00				
92	19:00				
93	20:00				
94	21:00				
95	22:00				

DW 82

96	23:00				
97	00:00	12/03/87			
98	01:00	Thursday			
99	02:00				
100	03:00				
101	04:00				
102	05:00				
103	06:00				
104	07:00				
105	08:00				
106	09:00				
107	10:00				
108	11:00				
109	12:00				
110	13:00				
111	14:00				
112	15:00				
113	16:00				
114	17:00				
115	18:00		826	12.13	Post-Mitigation Monitoring
116	19:00		435	6.20	with System Off
117	20:00		296	4.10	AB5 #1
118	21:00		343	4.81	
119	22:00		547	7.90	
120	23:00		823	12.08	
121	00:00	12/04/87	949	13.99	
122	01:00	Friday	996	14.70	
123	02:00		1230	18.25	
124	03:00		1551	23.11	
125	04:00		1740	25.97	
126	05:00		1935	28.93	
127	06:00		2003	29.96	
128	07:00		1784	26.64	
129	08:00		1711	25.54	
130	09:00		1769	26.41	
131	10:00		1725	25.75	
132	11:00		1966	29.40	Seal/vent level
133	12:00		1874	28.00	For 120-137
134	13:00		1754	26.19	Minimum- 12.08 pCi/l
135	14:00		1821	27.20	Maximum- 29.96
136	15:00		1688	25.19	Average- 23.94
137	16:00		1580	23.55	Std.Dev.- 5.30
138	17:00		1135	16.81	Crawl-Space Fan On, Low Flow
139	18:00		787	11.54	Rate
140	19:00		441	6.29	
141	20:00		295	4.08	
142	21:00		213	2.84	
143	22:00		160	2.03	
144	23:00		132	1.61	
145	00:00	12/05/87	107	1.23	
146	01:00	Saturday	129	1.57	

DW 82

147	02:00		129	1.57		
148	03:00		139	1.72		
149	04:00		117	1.38		
150	05:00		144	1.79		
151	06:00		157	1.99		
152	07:00		166	2.13		
153	08:00		185	2.41		
154	09:00		165	2.11		
155	10:00		169	2.17		
156	11:00		108	1.25		
157	12:00		87	0.93		
158	13:00		60	0.52		
159	14:00		44	0.28		
160	15:00		35	0.14		
161	16:00		57	0.47		
162	17:00		29	0.05		
163	18:00		35	0.14		
164	19:00		43	0.26		
165	20:00		37	0.17		
166	21:00		66	0.61		
167	22:00		80	0.82		
168	23:00		98	1.10		
169	00:00	12/06/87	93	1.02		
170	01:00	Sunday	103	1.17		
171	02:00		102	1.16		
172	03:00		120	1.43		
173	04:00		133	1.63		
174	05:00		137	1.69		
175	06:00		108	1.25	C/S Depress level	
176	07:00		116	1.37	For 140-180	
177	08:00		115	1.35	Minimum-	0.05 pCi/l
178	09:00		101	1.14	Maximum-	6.29
179	10:00		109	1.26	Average-	1.44
180	11:00		92	1.00	Std.Dev.-	1.10

Stop Post-Mitigation Monitoring

House DW 84	Continuous Radon Monitor Results				
Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/l

Line #	Time	Date	Counts/hr	pCi/l	Comments
1	00:00	03/17/88		0.00	
2	01:00	Thursday		0.00	
3	02:00			0.00	
4	03:00			0.00	
5	04:00			0.00	
6	05:00			0.00	
7	06:00			0.00	
8	07:00			0.00	
9	08:00			0.00	
10	09:00			0.00	
11	10:00			0.00	
12	11:00			0.00	
13	12:00			0.00	
14	13:00			0.00	
15	14:00			0.00	
16	15:00			0.00	
17	16:00			0.00	
18	17:00		229	3.08	Start Pre-Mit
19	18:00		340	4.76	Monitoring AB5 #1
20	19:00		341	4.78	
21	20:00		372	5.25	
22	21:00		412	5.85	
23	22:00		400	5.67	
24	23:00		443	6.32	
25	00:00	03/18/88	432	6.16	
26	01:00	Friday	500	7.19	
27	02:00		472	6.76	
28	03:00		532	7.67	
29	04:00		489	7.02	
30	05:00		467	6.69	
31	06:00		474	6.79	
32	07:00		492	7.07	
33	08:00		453	6.47	
34	09:00		488	7.00	
35	10:00		464	6.64	
36	11:00		451	6.44	
37	12:00		444	6.34	
38	13:00		418	5.94	
39	14:00		322	4.49	
40	15:00		360	5.07	
41	16:00		306	4.25	
42	17:00		302	4.19	
43	18:00		315	4.38	
44	19:00		329	4.60	

DW 84

45	20:00		321	4.47	
46	21:00		310	4.31	
47	22:00		284	3.91	
48	23:00		288	3.97	
49	00:00	03/19/88	353	4.96	
50	01:00	Saturday	399	5.66	
51	02:00		422	6.00	
52	03:00		463	6.63	
53	04:00		499	7.17	
54	05:00		486	6.97	
55	06:00		531	7.66	
56	07:00		496	7.13	
57	08:00		385	5.44	
58	09:00		348	4.88	
59	10:00		315	4.38	
60	11:00		289	3.99	
61	12:00		245	3.32	
62	13:00		213	2.84	
63	14:00		235	3.17	
64	15:00		211	2.81	
65	16:00		235	3.17	
66	17:00		243	3.29	
67	18:00		247	3.35	
68	19:00		263	3.60	
69	20:00		354	4.97	
70	21:00		442	6.31	
71	22:00		466	6.67	
72	23:00		435	6.20	
73	00:00	03/20/88	486	6.97	
74	01:00	Sunday	437	6.23	
75	02:00		420	5.97	
76	03:00		334	4.67	
77	04:00		295	4.08	
78	05:00		344	4.82	
79	06:00		336	4.70	
80	07:00		361	5.08	
81	08:00		307	4.26	
82	09:00		263	3.60	
83	10:00		241	3.26	
84	11:00		261	3.57	
85	12:00		252	3.43	
86	13:00		230	3.10	
87	14:00		165	2.11	
88	15:00		135	1.66	
89	16:00		136	1.67	
90	17:00		85	0.90	House open
91	18:00		71	0.69	to outside
92	19:00		140	1.73	
93	20:00		182	2.37	
94	21:00		259	3.54	
95	22:00		281	3.87	

DW 84

96	23:00		371	5.23		
97	00:00	03/21/88	374	5.28		
98	01:00	Monday	364	5.13		
99	02:00		390	5.52		
100	03:00		382	5.40		
101	04:00		358	5.03		
102	05:00		369	5.20	Pre-mit level	
103	06:00		348	4.88	For 20-107	
104	07:00		365	5.14	Minimum=	0.69 pCi/l
105	08:00		420	5.97	Maximum=	7.67
106	09:00		426	6.07	Average=	4.92
107	10:00		419	5.96	Std.Dev.=	1.59
108	11:00		281	3.87		
109	12:00		134	1.64	Install soil	
110	13:00		74	0.73	Depress system	
111	14:00		58	0.49		
112	15:00		63	0.57		
113	16:00		50	0.37		
114	17:00		40	0.22		
115	18:00		74	0.73		
116	19:00		128	1.55		
117	20:00		195	2.57		
118	21:00		233	3.14		
119	22:00		277	3.81		
120	23:00		335	4.69		
121	00:00	03/22/88	399	5.66		
122	01:00	Tuesday	421	5.99		
123	02:00		439	6.26		
124	03:00		487	6.99		
125	04:00		467	6.69		
126	05:00		554	8.00		
127	06:00		514	7.40		
128	07:00		450	6.43		
129	08:00		455	6.50		
130	09:00		419	5.96		
131	10:00		449	6.41		
132	11:00		403	5.72		
133	12:00		292	4.03		
134	13:00		132	1.61		
135	14:00		67	0.63		
136	15:00		37	0.17		
137	16:00		33	0.11		
138	17:00		26	0.00		
139	18:00		64	0.58		
140	19:00		45	0.29		
141	20:00		24	0.00		
142	21:00		24	0.00		
143	22:00		27	0.02		
144	23:00		52	0.40		
145	00:00	03/23/88	70	0.67		
146	01:00	Wednesday	61	0.53		

DW 84

147	02:00		43	0.26	
148	03:00		82	0.85	
149	04:00		47	0.32	
150	05:00		56	0.46	
151	06:00		41	0.23	
152	07:00		50	0.37	
153	08:00		105	1.20	
154	09:00		113	1.32	
155	10:00		158	2.00	
156	11:00		141	1.75	
157	12:00		135	1.66	Finish Install
158	13:00		75	0.75	Suction pits 12:34pm
159	14:00		41	0.23	
160	15:00		27	0.02	
161	16:00		18	0.00	
162	17:00		17	0.00	
163	18:00		19	0.00	
164	19:00		29	0.05	
165	20:00		22	0.00	
166	21:00		28	0.03	
167	22:00		44	0.28	
168	23:00		65	0.60	
169	00:00	03/24/88	101	1.14	
170	01:00	Thursday	96	1.07	
171	02:00		117	1.38	
172	03:00		149	1.87	
173	04:00		131	1.60	
174	05:00		148	1.85	
175	06:00		125	1.50	
176	07:00		124	1.49	
177	08:00		125	1.50	
178	09:00		117	1.38	
179	10:00		92	1.00	
180	11:00		89	0.96	
181	12:00		73	0.72	
182	13:00		58	0.49	
183	14:00		44	0.28	
184	15:00		27	0.02	
185	16:00		22	0.00	
186	17:00		20	0.00	
187	18:00		16	0.00	
188	19:00		19	0.00	
189	20:00		19	0.00	
190	21:00		22	0.00	
191	22:00		19	0.00	
192	23:00		17	0.00	
193	00:00	03/25/88	16	0.00	
194	01:00	Friday	20	0.00	
195	02:00		19	0.00	
196	03:00		20	0.00	
197	04:00		23	0.00	

DW 84

198	05:00		19	0.00
199	06:00		24	0.00
200	07:00		28	0.03
201	08:00		30	0.07
202	09:00		52	0.40
203	10:00		57	0.47
204	11:00		64	0.58
205	12:00		54	0.43
206	13:00		53	0.41
207	14:00		63	0.57
208	15:00		47	0.32
209	16:00		52	0.40
210	17:00		52	0.40
211	18:00		39	0.20
212	19:00		30	0.07
213	20:00		27	0.02
214	21:00		53	0.41
215	22:00		69	0.66
216	23:00		128	1.55
217	00:00	03/26/88	133	1.63
218	01:00	Saturday	141	1.75
219	02:00		163	2.08
220	03:00		152	1.91
221	04:00		215	2.87
222	05:00		192	2.52
223	06:00		158	2.00
224	07:00		153	1.93
225	08:00		113	1.32
226	09:00		124	1.49
227	10:00		135	1.66
228	11:00		132	1.61
229	12:00		153	1.93
230	13:00		168	2.16
231	14:00		144	1.79
232	15:00		153	1.93
233	16:00		169	2.17
234	17:00		192	2.52
235	18:00		181	2.35
236	19:00		216	2.88
237	20:00		232	3.13
238	21:00		275	3.78
239	22:00		275	3.78
240	23:00		240	3.25
241	00:00	03/27/88	282	3.88
242	01:00	Sunday	309	4.29
243	02:00		387	5.47
244	03:00		357	5.02
245	04:00		376	5.31
246	05:00		401	5.69
247	06:00		383	5.41
248	07:00		402	5.70

DW 84

249	08:00		343	4.81	
250	09:00		314	4.37	
251	10:00		269	3.69	
252	11:00		343	4.81	
253	12:00		269	3.69	
254	13:00		231	3.11	
255	14:00		222	2.97	
256	15:00		209	2.78	
257	16:00		264	3.61	
258	17:00		250	3.40	
259	18:00		241	3.26	
260	19:00		263	3.60	
261	20:00		285	3.93	
262	21:00		268	3.67	
263	22:00		267	3.66	
264	23:00		322	4.49	
265	00:00	03/28/88	371	5.23	
266	01:00	Monday	393	5.57	
267	02:00		367	5.17	
268	03:00		367	5.17	
269	04:00		383	5.41	
270	05:00		443	6.32	
271	06:00		397	5.63	
272	07:00		412	5.85	
273	08:00		371	5.23	
274	09:00		376	5.31	
275	10:00		354	4.97	
276	11:00		291	4.02	Begin Pre-Mit
277	12:00		231	3.11	CC at 11am
278	13:00		196	2.58	
279	14:00		165	2.11	
280	15:00		169	2.17	
281	16:00		149	1.87	
282	17:00		81	0.84	
283	18:00		51	0.38	
284	19:00		56	0.46	
285	20:00		79	0.81	
286	21:00		116	1.37	
287	22:00		157	1.99	
288	23:00		235	3.17	
289	00:00	03/29/88	258	3.52	
290	01:00	Tuesday	257	3.50	
291	02:00		281	3.87	
292	03:00		270	3.70	
293	04:00		311	4.32	
294	05:00		303	4.20	
295	06:00		254	3.46	
296	07:00		168	2.16	
297	08:00		158	2.00	
298	09:00		145	1.81	
299	10:00		175	2.26	

DW 84

300	11:00		163	2.08		
301	12:00		187	2.44		
302	13:00		221	2.96		
303	14:00		177	2.29		
304	15:00		142	1.76		
305	16:00		72	0.70		
306	17:00		30	0.07		
307	18:00		24	0.00		
308	19:00		25	0.00		
309	20:00		8	0.00		
310	21:00		14	0.00		
311	22:00		26	0.00		
312	23:00		28	0.03		
313	00:00	03/30/88	55	0.44		
314	01:00	Wednesday	90	0.97		
315	02:00		102	1.16		
316	03:00		133	1.63		
317	04:00		155	1.96	Pre-mit level ck	
318	05:00		213	2.84	For 276-324	
319	06:00		215	2.87	Minimum=	0.00 pCi/l
320	07:00		231	3.11	Maximum=	4.32
321	08:00		208	2.76	Average=	2.06
322	09:00		254	3.46	Std.Dev.=	1.32
323	10:00		279	3.84	Pick-up Pre-Mit	
324	11:00		281	3.87	CC at 10:45am	
325	12:00		273	3.75	Turn Fan on 12:10pm	
326	13:00		244	3.31		
327	14:00		249	3.38		
328	15:00		200	2.64		
329	16:00		173	2.23		
330	17:00		164	2.10		
331	18:00		136	1.67		
332	19:00		139	1.72		
333	20:00		150	1.88		
334	21:00		128	1.55		
335	22:00		126	1.52		
336	23:00		111	1.29		
337	00:00	03/31/88	111	1.29		
338	01:00	Thursday	110	1.28		
339	02:00		138	1.70		
340	03:00		138	1.70		
341	04:00		108	1.25		
342	05:00		141	1.75		
343	06:00		123	1.47		
344	07:00		120	1.43		
345	08:00		105	1.20		
346	09:00		115	1.35		
347	10:00		84	0.88		
348	11:00		128	1.55		
349	12:00		144	1.79		
350	13:00		117	1.38		

DW 84

351	14:00		108	1.25
352	15:00		111	1.29
353	16:00		81	0.84
354	17:00		102	1.16
355	18:00		67	0.63
356	19:00		64	0.58
357	20:00		72	0.70
358	21:00		66	0.61
359	22:00		62	0.55
360	23:00		64	0.58
361	00:00	04/01/88	90	0.97
362	01:00	Friday	63	0.57
363	02:00		71	0.69
364	03:00		65	0.60
365	04:00		92	1.00
366	05:00		106	1.22
367	06:00		77	0.78
368	07:00		76	0.76
369	08:00		73	0.72
370	09:00		63	0.57
371	10:00		71	0.69
372	11:00		65	0.60
373	12:00		84	0.88
374	13:00		79	0.81
375	14:00		49	0.35
376	15:00		56	0.46
377	16:00		64	0.58
378	17:00		55	0.44
379	18:00		41	0.23
380	19:00		37	0.17
381	20:00		30	0.07
382	21:00		52	0.40
383	22:00		46	0.31
384	23:00		62	0.55
385	00:00	04/02/88	32	0.10
386	01:00	Saturday	45	0.29
387	02:00		30	0.07
388	03:00		58	0.49
389	04:00		44	0.28
390	05:00		58	0.49
391	06:00		61	0.53
392	07:00		59	0.50
393	08:00		44	0.28
394	09:00		43	0.26
395	10:00		38	0.19
396	11:00		36	0.16
397	12:00		36	0.16
398	13:00		34	0.13
399	14:00		27	0.02
400	15:00		37	0.17
401	16:00		22	0.00

DW 84

402	17:00		43	0.26
403	18:00		31	0.08
404	19:00		31	0.08
405	20:00		23	0.00
406	21:00		16	0.00
407	22:00		26	0.00
408	23:00		22	0.00
409	00:00	04/03/88	24	0.00
410	01:00	Sunday	28	0.03
411	02:00		35	0.14
412	03:00		35	0.14
413	04:00		34	0.13
414	05:00		39	0.20
415	06:00		39	0.20
416	07:00		29	0.05
417	08:00		26	0.00
418	09:00		35	0.14
419	10:00		35	0.14
420	11:00		50	0.37
421	12:00		37	0.17
422	13:00		35	0.14
423	14:00		44	0.28
424	15:00		32	0.10
425	16:00		23	0.00
426	17:00		27	0.02
427	18:00		30	0.07
428	19:00		32	0.10
429	20:00		24	0.00
430	21:00		39	0.20
431	22:00		42	0.25
432	23:00		28	0.03
433	00:00	04/04/88	33	0.11
434	01:00	Monday	65	0.60
435	02:00		66	0.61
436	03:00		74	0.73
437	04:00		78	0.79
438	05:00		90	0.97
439	06:00		92	1.00
440	07:00		87	0.93
441	08:00		71	0.69
442	09:00		87	0.93
443	10:00		93	1.02
444	11:00		87	0.93
445	12:00		76	0.76
446	13:00		80	0.82
447	14:00		66	0.61
448	15:00		69	0.66
449	16:00		67	0.63
450	17:00		80	0.82
451	18:00		56	0.46
452	19:00		60	0.52

DW 84

453	20:00		56	0.46
454	21:00		63	0.57
455	22:00		64	0.58
456	23:00		71	0.69
457	00:00	04/05/88	92	1.00
458	01:00	Tuesday	95	1.05
459	02:00		88	0.94
460	03:00		112	1.31
461	04:00		98	1.10
462	05:00		84	0.88
463	06:00		101	1.14
464	07:00		97	1.08
465	08:00		103	1.17
466	09:00		101	1.14
467	10:00		94	1.04
468	11:00		92	1.00
469	12:00		76	0.76
470	13:00		60	0.52
471	14:00		57	0.47
472	15:00		55	0.44
473	16:00		46	0.31
474	17:00		39	0.20
475	18:00		35	0.14
476	19:00		29	0.05
477	20:00		18	0.00
478	21:00		23	0.00
479	22:00		26	0.00
480	23:00		26	0.00
481	00:00	04/06/88	23	0.00
482	01:00	Wednesday	13	0.00
483	02:00		25	0.00
484	03:00		28	0.03
485	04:00		37	0.17
486	05:00		50	0.37
487	06:00		41	0.23
488	07:00		54	0.43
489	08:00		61	0.53
490	09:00		74	0.73
491	10:00		83	0.87
492	11:00		68	0.64
493	12:00		87	0.93
494	13:00		102	1.16
495	14:00		107	1.23
496	15:00		121	1.44
497	16:00		77	0.78
498	17:00		87	0.93
499	18:00		121	1.44
500	19:00		110	1.28
501	20:00		131	1.60
502	21:00		114	1.34
503	22:00		87	0.93

DW 84

```
504     23:00                105      1.20
505     00:00 04/07/88        99      1.11
506     01:00 Thursday        96      1.07
507     02:00                135      1.66
508     03:00                117      1.38
509     04:00                134      1.64
510     05:00                141      1.75
511     06:00                 90      0.97
512     07:00                 97      1.08
513     08:00                 90      0.97
514     09:00                 85      0.90
515     10:00                 73      0.72
516     11:00                 80      0.82
517     12:00                 74      0.73
518     13:00                 67      0.63
519     14:00                 66      0.61
520     15:00                 83      0.87
521     16:00                 82      0.85
522     17:00                 87      0.93
523     18:00                 81      0.84
524     19:00                 76      0.76
525     20:00                 58      0.49
526     21:00                 51      0.38
527     22:00                 56      0.46
528     23:00                 46      0.31
529     00:00 04/08/88        43      0.26
530     01:00 Friday          47      0.32
531     02:00                 43      0.26
532     03:00                 41      0.23
533     04:00                 63      0.57 Soil Depress level
534     05:00                 48      0.34 For 328-538
535     06:00                 50      0.37 Minimum=     0.00 pCi/l
536     07:00                 29      0.05 Maximum=     2.64
537     08:00                 38      0.19 Average=     0.67
538     09:00                 33      0.11 Std.Dev.=    0.53
```

DW 84

Pressure Field Measured in Soil DW 84

Pits Active	Point for Dp	Distance to Source	Dp rel. to C/S ("WC)	Fan Flowrate ^(cfm)
AB	A	0	-1.416	43.5
	1	2	-0.342	
	2	6	-0.002	
	3	12	0	
	B	0	-1.344	
	4	2	-0.004	
	5	6	-0.002	
	6	12	-0.001	
ABCD	A	0	-0.933	87.3
	1	2	-0.22	
	2	6	-0.004	
	3	12	-0.001	
	B	0	-0.923	
	4	2	-0.001	
	5	6	-0.003	
	6	12	-0.002	
	C	0	-0.925	
	7	2	-0.001	
	8	6	-0.005	
	9	12	0	
	D	0	-0.924	

House DW 90 Continuous Radon Monitor Results

Pylon AB-5 Unit #	1	2	3	4	
Average Background	25.69	46.41	35.41	22.88	Counts/hour
Unit Calibration	1.1	1.22	1.1	1.16	Cpm/pCi/1

Line #	Time	Date	Counts/hr	pCi/1	Comments
1	00:00	12/01/87	0	0.00	
2	01:00	Tuesday	0	0.00	
3	02:00		0	0.00	
4	03:00		0	0.00	
5	04:00		0	0.00	
6	05:00		0	0.00	
7	06:00		0	0.00	
8	07:00		0	0.00	
9	08:00		0	0.00	
10	09:00		0	0.00	
11	10:00		0	0.00	
12	11:00		0	0.00	
13	12:00		0	0.00	
14	13:00		0	0.00	
15	14:00		0	0.00	
16	15:00		0	0.00	
17	16:00		0	0.00	
18	17:00		0	0.00	
19	18:00		0	0.00	
20	19:00		0	0.00	
21	20:00		916	13.34	Start Pre-Mitigation Monitor
22	21:00		945	13.78	AB5 #3
23	22:00		965	14.08	
24	23:00		947	13.81	
25	00:00	12/02/87	962	14.04	
26	01:00	Wednesday	963	14.05	
27	02:00		918	13.37	
28	03:00		940	13.71	
29	04:00		951	13.87	
30	05:00		1006	14.71	
31	06:00		999	14.60	
32	07:00		985	14.39	
33	08:00		1083	15.87	
34	09:00		1223	17.99	
35	10:00		1128	16.55	
36	11:00		1122	16.46	
37	12:00		1063	15.57	
38	13:00		1098	16.10	
39	14:00		1122	16.46	
40	15:00		1097	16.08	
41	16:00		1151	16.90	
42	17:00		1064	15.58	
43	18:00		1111	16.30	
44	19:00		1139	16.72	

DW 90

45	20:00		1315	19.39	
46	21:00		1316	19.40	
47	22:00		1356	20.01	
48	23:00		1461	21.60	
49	00:00	12/03/87	1494	22.10	
50	01:00	Thursday	1454	21.49	
51	02:00		1539	22.78	
52	03:00		1534	22.71	
53	04:00		1595	23.63	
54	05:00		1555	23.02	
55	06:00		1402	20.71	
56	07:00		1238	18.22	
57	08:00		1140	16.74	
58	09:00		1056	15.46	
59	10:00		961	14.02	
60	11:00		854	12.40	
61	12:00		738	10.65	
62	13:00		692	9.95	Pre-mit level
63	14:00		658	9.43	For 21-67
64	15:00		658	9.43	Minimum- 7.16 pCi/l
65	16:00		596	8.49	Maximum- 23.63
66	17:00		571	8.12	Average- 15.77
67	18:00		508	7.16	Std.Dev.- 4.09
68	19:00				Stop Pre-Mitigation Monitor
69	20:00				
70	21:00				
71	22:00				
72	23:00				
73	00:00	12/04/87			
74	01:00	Friday			
75	02:00				
76	03:00				
77	04:00				
78	05:00				
79	06:00				
80	07:00				
81	08:00				
82	09:00				
83	10:00				
84	11:00				
85	12:00				
86	13:00				
87	14:00				
88	15:00				
89	16:00				
90	17:00				
91	18:00				
92	19:00				
93	20:00				
94	21:00				
95	22:00				

DW 90

96	23:00	
97	00:00	12/05/87
98	01:00	Saturday
99	02:00	
100	03:00	
101	04:00	
102	05:00	
103	06:00	
104	07:00	
105	08:00	
106	09:00	
107	10:00	
108	11:00	
109	12:00	
110	13:00	
111	14:00	
112	15:00	
113	16:00	
114	17:00	
115	18:00	
116	19:00	
117	20:00	
118	21:00	
119	22:00	
120	23:00	
121	00:00	12/06/87
122	01:00	Sunday
123	02:00	
124	03:00	
125	04:00	
126	05:00	
127	06:00	
128	07:00	
129	08:00	
130	09:00	
131	10:00	
132	11:00	
133	12:00	
134	13:00	
135	14:00	
136	15:00	
137	16:00	
138	17:00	
139	18:00	
140	19:00	
141	20:00	
142	21:00	
143	22:00	
144	23:00	
145	00:00	12/07/87
146	01:00	Monday

DW 90

147	02:00				
148	03:00				
149	04:00				
150	05:00				
151	06:00				
152	07:00				
153	08:00				
154	09:00				
155	10:00				
156	11:00				
157	12:00				
158	13:00				
159	14:00				
160	15:00				
161	16:00				
162	17:00				
163	18:00				
164	19:00				
165	20:00				
166	21:00				
167	22:00				
168	23:00				
169	00:00	12/08/87			
170	01:00	Tuesday			
171	02:00				
172	03:00				
173	04:00				
174	05:00				
175	06:00				
176	07:00				
177	08:00				
178	09:00				
179	10:00				
180	11:00				
181	12:00				
182	13:00				
183	14:00				
184	15:00				
185	16:00				
186	17:00		314	4.22	Start Post-Mitigation
187	18:00		394	5.43	Monitoring,Seal/Vent C/S
188	19:00		436	6.07	AB5 #3
189	20:00		444	6.19	
190	21:00		428	5.95	
191	22:00		416	5.77	
192	23:00		426	5.92	
193	00:00	12/09/87	357	4.87	
194	01:00	Wednesday	370	5.07	
195	02:00		300	4.01	
196	03:00		250	3.25	
197	04:00		237	3.05	

DW 90

198	05:00		236	3.04		
199	06:00		205	2.57		
200	07:00		184	2.25	Seal/vent c/s level	
201	08:00		177	2.15	For 187-205	
202	09:00		188	2.31	Minimum=	2.15 pCi/l
203	10:00		207	2.60	Maximum=	6.19
204	11:00		216	2.74	Average=	3.97
205	12:00		186	2.28	Std.Dev.=	1.52
206	13:00		108	1.10	Sub-Poly Suction	
207	14:00		74	0.58	On 14:00 Hrs	
208	15:00		52	0.25		
209	16:00		47	0.18		
210	17:00		48	0.19		
211	18:00		54	0.28		
212	19:00		47	0.18		
213	20:00		42	0.10		
214	21:00		49	0.21		
215	22:00		77	0.63		
216	23:00		95	0.90		
217	00:00	12/10/87	75	0.60		
218	01:00	Thursday	108	1.10		
219	02:00		107	1.08		
220	03:00		120	1.28		
221	04:00		131	1.45		
222	05:00		125	1.36		
223	06:00		176	2.13		
224	07:00		200	2.49		
225	08:00		214	2.71		
226	09:00		211	2.66	1 SPS level	
227	10:00		188	2.31	For 208-231	
228	11:00		168	2.01	Minimum=	0.10 pCi/l
229	12:00		169	2.02	Maximum=	2.71
230	13:00		131	1.45	Average=	1.20
231	14:00		121	1.30	Std.Dev.=	0.85
					Stop Post-Mitigation Monitoring	

Dp Measurements for Sub-poly suction systems.
Distance Dp (inches of water)

from Suction Point (ft)	DW90
-----	-----
0	-1.045
2	
3	
4	-0.031
6	-0.015
12	0

Q(cfm)

The following Table lists the mitigation costs for the initial houses mitigated during this demonstration.

Nashville Radon Mitigation Demonstration
Mitigation costs (preliminary)

House ID	Mitigation Phase	Costs	
		Estimated	Actual
DW 03	A-Seal,caulk 1st sub-poly dep	$ 850	$ 850
	B-2nd sub-poly	750	
DW 27	A-1st subpoly sys	1,169	1,169
	B-2nd subpoly pt	415	415
	C-seal,caulk	490	
	D-depress c/s	190	
DW 29	A-seal,caulk 1st subpoly	1,345	1,345
	B-2nd subpoly	280	280
	C-seal to walls	350	
DW 31	A-4pt soil dep	1,857	1,857
DW 60	A-seal, caulk 1pt subpoly	1,174	1,174
	B-pressurize c/s	685	685
DW 66	A-seal, caulk 1pt subpoly	922	922
DW 82	A-seal, caulk dep c/s	1,190	1,190
DW 84	A-4pt soil dep	995	995
	B-lay EPDM	400	
	C-Enkadrain	300	
	D-seal to walls	550	
DW 90	A-seal, caulk 1pt subpoly	853	853
DW 43	A-2pt subslab wall dep	2,494	2,494

Nashville Radon Mitigation Demonstration
Mitigation costs (preliminary)

DW 58	A-subslab dep	4,561	**
	B-pres bsmt	300	300
DW 78	A-2pt subslab	1,255	1,255
	B-cover soil/walls	610	610
	C-seal/pres bsmt	885	
DW 12	A-2pt subslab	1340	1340
	B-subpoly sys	406	
DW 14	A-2pt subslab cover c/s	1650	1650
	B-wall dep	345	345
DW 41	A-1pt subslab isolate c/s	785	785
	B-drain tile sys	1000	
	TOTALS	$29,711	$19,529

Note: ** Work not performed during period of mitigation.

Terradex
Radon Detection Products
Tech/Ops Landauer, Inc.
2 Science Road
Glenwood, Illinois 60425-1586
Telephone (312) 755-7000

Tech/Ops
Landauer

Robert V. Wheeler
Marketing Manager

December 5, 1988

Bobby E. Pyle, Ph.D.
Research Physicist
Southern Research Institute
Environmental Sciences
  Research Dept.
2000 Ninth Avenue South
PO Box 55305
Birmingham, AL 35255-5305

Dear Dr. Pyle:

As we discussed by phone last Thursday, we have examined the Type SF detector results you referred to me during the Denver meeting and find that six of those results were reported in error as a result of a detector positioning and identity change that was implemented shortly before these detectors were fabricated. I have listed the detector pairs and their respective readings. The underlined reading is the correct value; the remaining readings are incorrect and should be voided.

Detector Number	Reported Results
619128, 619062	6.3, 0.9
796505, 619066	1.4, 0.4
619071, 619148	0.6, 7.2
619112, 619160	0.4, 15.6
619103, 619151	0.3, 3.0
619144, 619094	19.7, 1.0
619083, 619085	1.3, 12.3

I have also instructed our people to credit your account for the six defective readings.

Sincerely,

TECH/OPS LANDAUER, INC.

Robert V. Wheeler

Robert V. Wheeler
Marketing Manager
Radon Detection Products

RVW/ml

Date: February 4, 1988

MEMO to: QA File Project 6411-10

From: B.E. Pyle

Subject: Problems with charcoal canister blinds

Copies: ADW, CSF, BEP, DivF

On January 20-22, 1988, five Scientific Analysis, Inc. charcoal canisters were exposed for us by EPA at the Eastern Environmental Radiation Facility i Montgomery, AL. These detectors were exposed in their Chamber B for 48 hours at an average Radon level of 34.0 + _0.7 pCi/l, at a temperature of 70 °F and a relative humidity of 15 ±5% as shown on the accompanying letter from Ed Sensintaffar of that lab. The detectors were analyzed on January 24, 1988 by SAI with the following results:

SRI ID	SAI ID	Test Results
BHM-1	D-3098	46.8 pCi/l
BHM-2	D-3106	46.7 "
BHM-3	D-3086	47.1 "
BHM-4	D-3095	46.6 "
BHM-5	D-3101	49.1 "
Average		47.26 pCi/l
Percent Error		39%

After talking with Allen Gunn of SAI about this error, he got in touch with Sam Windham at EPA, EERF about the problem. Allen called back to express his ideas as to why the large error. Allen believes that there are regions in the EPA Chamber B (the new large chamber) in which the Radon concentrations are not uniform thus the reading obtained depends upon where in the chamber the cans were located. Also, Allen could not understand why the relative humidity in the chamber (15%) was so low. This RH is much lower than that at which the charcoal canisters are made that they, in fact, lose weight during exposure. He suggested that I get in touch with Sam Windham to explore alternative means of doing "blinds". In talks with Sam, he related the following information. During Rounds 1-3 of the Proficiency Tests the charcoal detectors were exposed in Andy George's lab at the Environmental Measurements Laboratory (EML) in New York (a DOE lab). During these rounds very few problems were encountered with the people using charcoal cans. The reported values from all the participants were apparently normally distributed about the level of the exposure chamber. For round 4 the Chamber B in Montgomery was used. The results of this round showed that the measured radon levels were biased toward the high end by as much as 16%, the distribution of reported values gave a skewed distribution. Sam related that much work was carried out to determine the source of this bias. The conclusion was that in Chamber B (which is a walk-in chamber) the air movements are much greater than in previous chambers, both George's and Sam's Chamber A (which is a 4' by 4' by 8' enclosure). As a result the canisters are not subjected to stagnant air conditions and there is a continuous supply of fresh radon laden air. In stagnant air conditions the charcoal causes local depletion of the radon in the air immediately above it. In stagnant conditions the radon is replaced through diffusion while in moving air conditions the radon levels are controlled by convection which is more rapid than diffusion. As a result, the measured levels in non-stagnant conditions are higher than those in stagnant conditions. Apparently, these levels in chamber B are different by approximately 16%. EPA made the decision to continue using chamber B in the belief that true stagnant air conditions are never achieved in locations in homes where the detectors are used. As to why the chamber was run at such a low RH no good answer was possible. Sam did offer to run more blinds at higher RH values and would do so in either the old Chamber A (stagnant air conditions) or in Chamber B (non-stagnant air conditions).

With regards to the Nashville project, the RH values in the homes and particularly in the crawl space measurements are believed to be in the 50 to 90% humidity range. In some of the homes there are not air handling equipment to produce air currents. These homes are heated with radiant floor or ceiling heaters. These conditions more closely resemble stagnant conditions. In some of the homes there are central heating systems and could approximate the non-stagnant conditions in the EPA chamber B.

We propose to do the following: ask Sam to expose 3 canisters in Chamber A and 3 in Chamber B. Each chamber will be run at the same humidity level and 50% or greater. The radon levels in each chamber should be nearly the same and about 30 to 40 pCi/l. With these blinds we can get an estimate of the error in using canisters in the various houses and hopefully can get better blind results from SAI's analysis.

Southern Research Institute 2000 Ninth Avenue South / P.O. Box 55305 / Birmingham, Alabama 35255-5305 / (205) 323-6592

April 8, 1988

Edwin L. Sensintaffer
U.S. Environmental Protection Agency
Eastern Environmental Radiation Facility
1890 Federal Drive
Montgomery, AL 36109

Dear Ed:

As we agreed in our telephone conversation on Friday April 7, I am enclosing six (6) charcoal canisters from Scientific Analysis, Inc. (SAI) which we use in Nashville and six (6) of your EPA canisters we are using in the Florida houses. If possible we would like to have the canisters exposed in the small radon chamber while you have air movement in one side and relatively still air in the other. If this is not possible then we will take split exposures in both the large chamber (with air movement) and the small chamber (with little or no air movement). The exposure ranges for radon level and relative humidity can be anywhere from 20 to 50 pCi/l and 50 - 80% R.H. If possible expose the cans as follows:

SAI 3 cans with little or no air movement
3 cans with air movement

EPA 2 blue and 1 purple batch with little or no air movement
2 purple and 1 blue batch with air movement.

After the exposure please hold your EPA canisters for a couple of days before reading and the SAI cans hold likewise for a couple of days then call Allen Gunn (or Ronda) at 271-0643 and he will have someone pick them up for analysis.

If you have problems getting these conditions, or have other questions, call Dr. Ashley Williamson since I will be in Nashville all next week.

Sincerely,

Bobby E. Pyle, Ph.D.
Research Physicist

BEP/fea
Enclosures
Project 6411-10/20

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Center for Environmental Research Information
Cincinnati, Ohio 45268

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300
AN EQUAL OPPORTUNITY EMPLOYER

If your address is incorrect, please change on the above label tear off; and return to the above address.
If you do not desire to continue receiving these technical reports, CHECK HERE ☐, tear off label, and return it to the above address.

Publication No. EPA- 600/8-90-061